MUSEUM OF PRACTICAL GEOLOGY
AND GEOLOGICAL SURVEY.

RECORDS

OF THE

SCHOOL OF MINES

AND OF

SCIENCE APPLIED TO THE ARTS.

VOL. I. PART I.

INAUGURAL AND INTRODUCTORY LECTURES TO THE COURSES FOR
THE SESSION 1851-2.

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NOTICE.

It is proposed in these "Records" from time to time to publish accounts of researches carried on at the School of Mines, and during the course of the Geological Survey of the United Kingdom. To these will be added occasional notices of such discoveries and researches in Foreign Countries as may be considered important to the progress of the British Arts and Manufactures illustrated in the Museum of Practical Geology.

H. T. DE LA BECHE.

Inaugural Discourse, delivered at the Opening of the School of Mines and of Science applied to the Arts,
6th November 1851.

By Sir HENRY T. DE LA BECHE, C.B., F.R.S., &c.

WE are this day assembled to inaugurate a system of instruction new to our country; one which does not interfere with existing institutions,—on the contrary, it may be considered as assisting several, inasmuch as while it provides for a want which they do not supply, it refers to knowledge which they teach.

That this establishment should be the means of affording instruction in a particular direction,—an instruction tending more especially to illustrate the application of Geology, and of its associated sciences, to the useful purposes of life, was early decided. In 1839, four years after the first collections were made for the Museum of Practical Geology, the sanction of the Treasury was given to lectures having that application for their object. The system of instruction we commence this day is, therefore, not founded on any new view, twelve years having elapsed since lectures of a similar general character were authorized. That these lectures have not been given has arisen from the want of a proper theatre in which to deliver them, and from the absence of other appliances not, until now, at our command.

Referring thus to the early condition of this establishment, a few words on its origin may, perhaps, not be altogether out of place. It was while (in 1835) conducting the Geological Survey, then in progress, under the Ordnance, in Cornwall, that being forcibly impressed that this survey presented an opportunity, not likely to recur, of illustrating the useful applications of Geology, I ventured to suggest to Mr. Spring Rice (now

Lord Monteagle), then Chancellor of the Exchequer, that a collection should be formed, and placed under the charge of the Office of Works, "containing specimens of the various mineral substances used for roads, in constructing public works or buildings, employed for useful purposes, or from which useful metals were extracted, and that it should be arranged with every reference to instruction;" as, by the adoption of this course, "a large amount of information which was scattered might be condensed, and those interested be enabled to judge how far our known mineral wealth might be rendered available for any undertaking they are required to direct, or may be anxious to promote, for the good or ornament of their country."

The proposal was favourably received, and its object effectually supported by Sir Francis Baring (then Secretary of the Treasury), the late Lord Bessborough (at that time Chief Commissioner of Woods and Works), and by Mr. Trenham W. Philipps, the present Secretary of the Office of Works; from the latter most material aid has always been received during the various changes of administration which have taken place during the last sixteen years. From the statesmen of the different governments who have had this establishment under their consideration since its commencement, we have, without exception, received all kindness and encouragement. As he has passed away from among us, it may be permitted me, without fear of a misconstruction of motives, to refer to the late lamented Sir Robert Peel, as one of those to whom we have been most materially indebted for our progress. He ever expressed a warm interest in our advance, was one of our frequent visitors, and not only by words, but by acts, proved the real interest he took in our success.

As soon as a locality was found for the deposit of specimens*, presents poured in in abundance, and our Cornish mining friends especially may be said, "one and all,"† to have assisted us. The collections, including models of mines and mining machinery, accumulated rapidly. A laboratory, to be alike

* In a house belonging to the Crown, in Craig's Court, Charing Cross.

† The Cornish motto.

useful to the public and the government departments, was added, and a chemist, who was also the curator*, was appointed. The collections continued to augment by the exertions of the Geological Survey, and by presents, so that there was not sufficient space for them in the house first assigned for their reception. An adjoining house, at that time the Earl Marshal's Office, was added to it. This even became insufficient, and a part of the collections was established elsewhere.† Finally, the necessity of proper accommodation became so pressing, especially after 1845, when the Geological Survey and the Museum of Practical Geology were placed under the same department ‡, that—a fitting opportunity occurring—the building in which we are now assembled was erected.

We propose to instruct by means of our collections, our laboratories, our mining record office, our lectures, and the Geological Survey;—thus teaching as well in the field as in this building, and so that the pupils can become practically acquainted with mining in our various mineral districts, be able to study geology, and those of its applications requiring it, on the ground itself, and so unite, in a manner not hitherto attempted, and yet in one for which our opportunities amply provide, a sound combination of science and practice; a combination also kept steadily in view in our laboratories, and in all branches of the instruction upon which it is now purposed to enter.

It may, in the first place, be desirable to call your attention to the objects proposed by our collections. They are not intended to be mere assemblages of specimens, striking either for their brilliancy, colour, or form. In whatever department they may be found they are intended to be instructive with reference to the especial object proposed in that department, and to be employed in illustration of the teaching by lectures

* The late Mr. Richard Phillips, F.R.S.

† In Whitehall Yard.

‡ The Chief Commissioner of Woods, Works, &c., at that time the Earl of Lincoln (the present Duke of Newcastle).

or other means adopted by those in charge of the different departments confided to them. The collections are arranged for this purpose, and so, also, that the general public, who have free admission to them during the first three days of the week, may readily understand them, by means of succinct treatises on each subject, to be had separately, and at small cost. In them the reason for the presence of the various specimens will be assigned, and it is thus hoped that much useful and valuable information may be afforded.

Let me, in the first place, briefly call your attention to the specimens of the stones applicable to architecture and engineering. This collection is based on one formed during the investigation undertaken in search of the best stone to be employed in the New Houses of Parliament, or the New Palace at Westminster, as the building is often termed. It had become evident that more care than had hitherto been taken with regard to the stone employed in our public edifices was needed, and that public buildings should not be constructed of materials so little capable of resisting atmospheric influences that they readily give way before them, their external enrichments being in some cases defaced even in a few years. We possessed an abundance of different building stones, the durability of which could be seen in various structures in different parts of the country, the quarries themselves could be studied for their capability of supply, and the cost of the transport of the stone furnished by them in different directions could be ascertained. The results of this investigation will be found in the report on the subject presented to Parliament in 1839, and our cases contain the collection then formed. Since that time all diligence has been employed to add to it, care being taken to obtain the information needed; and every specimen has an inscription upon it, showing the edifices wherein the stone has been used, so that the architect can, at a glance, see its general character, and at the same time learn where to study the effects of the atmosphere upon it. A few of our building stones have been employed in illustration of their capability for statuary; thus, excellent copies will be found of the Farnese

Hercules in Portland stone, of the Giustiniani Minerva in Huddlestone dolomite, and of a bust of Antinous, as Bacchus, in Anston dolomite.*

It may, in passing, be of interest to observe that the Normans seem generally to have been very careful in their selection of the stone employed in the erection of their different edifices in this country, as is especially shown in those to which additions have afterwards been made, where we find that they had selected stone, even from comparatively considerable distances, which their successors neglected, employing a far less durable substance nearer the very edifice in which the good qualities of the material used by the Normans were abundantly apparent.

The lower hall, likewise, proves that as regards ornamental marbles, serpentines, porphyries, and granites, our land furnishes an ample supply, and that they are alike remarkable for their beauty and the facility with which they can be procured. It will be observed that they have been, when practicable, arranged so as to produce an architectural effect, thus enabling the architect, and those requiring his aid, to judge of their general appearance, and their application to the purposes thought desirable.

Still, confining our attention to the mineral substances employed by the architect or engineer, the next valuable assemblage of objects embraces the various baked materials which man for so many ages has used for the structures raised by him. This series will be found not wanting in value, and it will be our endeavour to render it instructive. The Jermyn-street front of this building, constructed with Suffolk brick and

* Reference was made to specimens of different kinds on the table, as illustrating the subject. It was briefly pointed out that building stones might be conveniently divided into, first, those cut by the tool, such as the various kinds of limestone and marble ; and secondly, those pounded by the tool, such as a great variety of sandstones, porphyries, granites, and the like. Attention was called, among the former class, to the Anston stone, or dolomite (a compound of carbonate of lime and carbonate of magnesia) employed in the new Houses of Parliament, a stone similar to that used in the Norman front of Southwell church, in Nottinghamshire, the tool marks on which are nearly as fresh as when it was first erected.

Anston dolomite, is intended to illustrate the intermixture of two valuable materials,—the one natural, the other artificial; and it will, at some future time, be interesting to observe the relative resistance presented by each to atmospheric influences.

Our ceramic collection is extensive, and, of its kind, unique. Especial reference is made in it to the materials and forms employed in the ceramic manufactures of this country from early times. The Staffordshire series reaches as far back as 1500, and is brought up to the present time, the last additions being objects shown at the late Great Exhibition of the Industry of all Nations. This series is based on a collection made in Staffordshire by Mr. Enoch Wood, than whom no one could be more capable of selecting the best illustrations of the progress of the Staffordshire Potteries. In the hall will have been observed a tesselated pavement, designed after portions of those in a Roman villa, at Woodchester, in Gloucestershire, and formed of compressed clays, afterwards baked, by a patent process, a beautiful illustration of progress in this kind of manufacture.* The other English porcelains and earthenwares, such as those of Chelsea, Derby, Plymouth, Worcester, and Swansea, are also represented by carefully selected examples, so as to illustrate their history, the circumstances connected with the materials used, and the forms adopted. I may point to the specimen showing the earliest transfer of prints to porcelain, by Dr. Wall, with the date of 1751, as exemplifying attention to the history of this branch of industry; while, as you will observe, another specimen,—a Staffordshire one, however,—shows the present state of this kind of transfer. In the first case only one colour was imprinted on the porcelain; in the second numerous colours, forming a picture.

The vitreous series will likewise be found one presenting

* Water, as employed usually in ceramic manufactures, may be regarded as a mere tool, by which the material is easily worked. It has to be removed as much as possible by evaporation, before the firing is effected. The tesseræ alluded to in the text are made with materials nearly dry, with only sufficient moisture to cohere when pressed. Thus they are very dense, from the heavy pressure to which they are subjected, and remain so even after baking.

much interest. This also is arranged historically, and at the same time with reference to materials, and mode of manufacture. In this series we have to pass through Venetian, Roman, Greek, Egyptian, and Assyrian glass for proper illustration. The collection has been found alike interesting to the classical student and the modern manufacturer. The analyses that have been already made of some of the glass are highly illustrative in both respects, and these researches will be further prosecuted.*

We now reach the mining collections. The metallic series is arranged so as to show the various ores of the different metals, their mode of occurrence in the earth, the methods employed in their extraction, and the means used for rendering them marketable. At this point the labours of the miner terminate, and those of the metallurgist commence. These are also fully illustrated, and the qualities of the different metals, either alone, or mingled as alloys, in their application to arts and manufactures carefully exhibited. In the department of the ores it became needful to include not only those from our colonies (attention to our colonial products being one of the objects of this institution), but also those of many foreign lands, in order to accustom our miners to kinds and modifications of them, with which they are not familiar. Those who have during many years watched the progress of our mines will be fully aware how essential this may be to their effective progress. It is well known that large sums of money have been from time to time lost from a want of this knowledge, quantities of strange ores having been washed down rivers, or into the sea, before their value was known. A recent instance may illustrate this point. Ores, regarded only as important for the copper they contained, were raised on some property of the Duke of Argyll, in Scotland. After a time the works were abandoned, as the copper found in the ores was not sufficiently abundant to pay for the cost of obtaining them, and much was thrown aside as not worth dressing. The Duke

* For example, the Roman glass, found near Naples, seems to have a common character, and to be formed, as chief ingredients, of the silicates of lime and soda, the latter probably derived from the natron lakes of Egypt.

impressed with a certain character in the ores, brought specimens to this institution for analysis, when it was found that they contained 11 per cent. of nickel, a valuable metal, and, as you are aware, extensively employed at this time in different alloys, such as those known as German silver. Other portions have been found still richer in this metal, and the ore thrown away and dispersed has been valued at from 30*l.* to 40*l.* per ton. It may be added, that even after this ore was thus found to contain nickel, it was stated, from an assay elsewhere, not to afford this metal; so little diffused is effective metallurgical knowledge in this land.*

Both the composition of ores, and their mode of occurrence, involve questions of high scientific interest, bearing upon practical applications of great importance. Let us for a moment regard the accompanying diagram†, representing a proportional and sectional view of our earth, with the atmosphere, and a hundred miles beneath the surface of the sea; of the matter really at that depth we know nothing, but it is convenient, as showing that if we did possess that knowledge, the portion of the earth then known would be exceedingly small. As far as we are acquainted with the rocks upon the surface of our spheroid, they are formed of various oxides of different substances, supposed simple. The exceptions, as regards the general volume they occupy, are insignificant. In certain cracks, fissures, or other cavities in this mass of oxides, we find matter under other conditions, derived probably from beneath, and, as it were, affording something of an insight into substances there more abundantly occurring. There may be secondary conditions of the same substances, but still the inference remains that these fissures and other cavities may afford, by careful study, information in the direction mentioned, and it is important to remember that while the mean density of the surface of the earth is taken at 2·6, that of the whole mass is inferred to be

* Even within these few days a case has occurred in Devonshire where a field wall was constructed of grey copper ore, and the breaking of a gate post led to a knowledge of the fact. This happened in a mining district.

† Referring to one exhibited.

4·39, pointing to heavier matter inwards, whatever views we may entertain of the diminution of density produced by heat in the interior.

At first sight the practical value of such an inquiry may appear very remote. It is, however, like all investigations in high science, one which may bear fruit if properly followed out. We have, in the first place, to couple it with the observed modes of occurrence of the ores of the metals in fissures and other cavities, and carefully study why it happens that given conditions produce given results; as, for example, why it is that in Derbyshire,* where the same fissures traverse different rocks, only certain of them have, as it were, permitted the accumulation of lead ores near them, while others, as a general fact, have repulsed them. Such facts are not new to the miner; he is familiar, in different districts and lands, with the modifications and changes observed in the assemblages of ores of all kinds in contact with various rocks in the same range of fissures. The cause of these facts is an object of science, and already progress has been made; when found it becomes a guide of the highest importance to the practical miner.

Our collections of the mode of occurrence of the ores are very extensive, and great care is taken to make them effectively instructive. As to the methods of their extraction, models and drawings of various kinds show not only the different machines used for draining mines, but also the mode of raising the ores. Great attention is given to this subject. So also with respect to the dressing of the ores, the like regard to proper illustration is paid.

The metallurgical series contains examples as well of foreign as of our own methods of reducing the metals. Our cases are full of objects of interest in this department, as well as of illustrations of the uses of the metals, and of their compounds or alloys in arts and manufactures, including an electrotype series of much interest. The ductility of copper, as shown in the specimens on the table, and as formed into the elegant vessels

* Pointing to a diagram on the wall.

exhibited, will illustrate the manner in which this subject is treated, as will also the statuettes before you, formed of bronze composed of the alloy which our analyses have shown to be that most effective for casting figures, and which is, at the same time, one that the Greeks and Romans seem to have adopted.

Quitting the metalliferous series, we may mention that the methods of working coal receive ample attention, due regard being had to that important object, the ventilation of collieries, Indeed we endeavour to be as complete as possible in all things illustrative of the working of mines, of whatever kind these may be, and are not neglectful of a variety of mineral products, such as rock salt, sulphur, alum, plumbago, and the like, which it would be out of place further to notice.

Our very important and valuable palæontological collection should nevertheless be specified, since it may be regarded as the most perfect of its kind: it is the joint result of the labours of the Geological Survey, and of a mass of presents, even of whole private collections. Of the value of such collections it would be superfluous now to insist, since, as you are aware, all mining schools strive to possess them in as extended a form as possible; those who desire and support such schools being fully sensible of their important bearing on geological investigations, and consequently on the practical applications of geology. Did time permit, it would be easy to show how many mistakes have been made, especially in seeking for coal, thousands having been thrown away in a vain search for that which a very moderate acquaintance with palæontology would have prevented.

Donations to our collections have been again mentioned. It may be here observed that the larger portion of them are composed of presents, showing, as we hope, that the public are not dissatisfied with our endeavours to be useful. From the Great Exhibition alone the donations we have received must already have reached a value of not less than 3,000*l.*, and these presents have not yet ceased.

Passing over the series illustrating the formation of rocks at different geological times, and of the changes which have taken place in them since their deposit, many of which have practical bearings,—as, for example, the roofing slates formed by the

action which has been termed *cleavage*, and which so distinguish themselves for durability from those obtained by the simple lamination of rocks, corresponding with the planes of their deposit,—we come to the Mining Record Office.

This office was established in connexion with the Museum of Practical Geology in 1840. It was so for the purpose of collecting information respecting the distribution and produce of our mines,—and for procuring plans and sections not only of modern workings but also of abandoned mines,—the last especially important, as being the means of saving life, or the erroneous outlay of capital, by preventing new works from being carried on in wrong directions. It is but right to remark that we have always received hearty co-operation from the mining interest in carrying out the objects of this office. To illustrate the value of the plans and sections of abandoned mines, let us select from those on the wall before us a section of Wheal Alfred, Cornwall. It had been stated that the working of this mine, at one time a most prosperous one (having afforded a profit of 140,000*l.*), had ceased on account of much water, which the engines of the time were supposed not equal to raise. A company was about to be formed, when it was suggested that documents known to be in our Record Office should be examined. The section before you at once pointed out, by the prices of work entered upon it, that the mine had been abandoned for its poverty, the undertaking was in consequence dropped, and a large useless outlay of money avoided. The section is the present of Mr. John Taylor, to whom the Mining Record Office is most especially indebted for numerous and important documents of the like kind.

From the aid also afforded by those interested we are gradually acquiring more real information respecting the products of our mines than has been hitherto procured; a subject alike important for the miner and the public. The copper ores raised have long been well ascertained, and the same may be said for the tin, even now that the "tin coinage" of Cornwall and Devon has ceased. We have been enabled to produce lead returns during the last four years, of an accuracy not before known. We are now proceeding with the other metals and

coal, and hope, at no distant date, to produce effective returns of these also.

The laboratories, one for general chemistry, the other for metallurgy, and their bearing upon a School of Mines and of Science applied to the Arts, may be said to speak for themselves; their usefulness and importance are evident. A special metallurgical laboratory has not been previously attached to any place of instruction in the country. With regard to the work executed at these laboratories for the public service, we may point, as one of the last of our endeavours to be useful, to the inquiry undertaken for the Admiralty as to the coals of this country best suited to the steam navy, three reports on which, completing the investigation, have been presented to Parliament. It will be obvious that to obtain the greatest amount of locomotive power from the smallest volume of fuel, and to avoid the evolution of smoke, are points of no slight importance for our steam navy.

As it is contemplated that our students should avail themselves of the Geological Survey for field instruction, including actual mining, it may be desirable, perhaps, to call your attention to certain of the maps and sections constructed by that survey, and now before you, inasmuch as, while they refer to geology as a science, they are at the same time available for its industrial applications. Thus you will observe that all mineral veins and the outcrops of coal-beds are inserted on these maps, as well as the boundaries of the various rocks, and with the exactitude required. The sections, in like manner, show the mode of occurrence of the coal and ironstone beds in certain districts, and of the mineral veins in others.

A point of much interest, both in its scientific and practical bearing, is now engaging the attention of the Survey in central England, namely, the probable depths and chances of obtaining coal beneath the red sandstones and marls there so abundant. There is reason to consider that, notwithstanding the many difficulties with which the subject is surrounded, very considerable advance has been made in this direction.

That the applications of such a survey are not confined to mining, you need scarcely be reminded; its aid to agriculture

and engineering are equally important. Our every-day's experience along coasts shows us how needful it is that the engineer should, as well as the geologist, study them. Let us, for example, consider this cove*,—there are hundreds such as it to be found on our coasts. The mode in which it is silted up is apparent to you, and yet many an artificial cove has been constructed, at great cost and loss, which was as certain to be filled up by silt and sand as this has been and must be. No doubt there are conditions where the silting up may be so small as to be comparatively unimportant, but the probability of these conditions requires the study pointed out. While on this subject, let me also briefly call your attention to the silting up of estuaries. Those who are engaged on the Geological Survey have often to consider it both with reference to the mode of deposit of certain rocks, and to the changes effected by it at the present day. The plan before you shows an estuary with the boundaries of high and low water, a spit of shingles running in front of part of the estuary, separating it from the sea, and the comparatively narrow entrance for the ingress and egress of the tide. The whole is the result of the balance of certain conditions by which the channel from the sea to the estuary is kept clear, and vessels of a certain class can enter and depart. The body of water entering and passing out is important; and yet what do we often find done, and done too by Act of Parliament? The body of water entering, and consequently passing out, is diminished for the purpose of *reclaiming*, as it is termed, certain mud-banks, often extensive; thousands of tons of water are thus sometimes cut off from performing the work by which they aided in keeping the channel to the sea clear; the bottom of the channel rises, and the port is damaged. No doubt the mudbank may be converted into fertile land, but at what loss! The natural causes for deteriorating estuary harbours are often bad enough, but why artificially strive to injure them? Other examples of the application of geology to engineering and the useful purposes of life generally might be readily

* Pointing to section on the wall.

adduced; these, however, may suffice to illustrate their importance.

Although the raw mineral produce of Great Britain and Ireland is valued at 24,000,000*l.* per annum, or about four ninths of that of all Europe, including these islands (the coal estimated at the pit mouth, the iron in the pig, and so on), there existed until now no means in this country for affording needful instruction to those who thus raise so great an amount of mineral matter, to be afterwards employed in affording occupation to an additional and large part of our population; all was left to chance, and the result is well known. Many who can afford it go to other lands to study in the mining schools provided by their governments; some fight through their difficulties at home, becoming valuable and useful men; while the mass of our miners remain uninstructed, except so far as they can pick up practical information from each other in the mines, seldom being conversant but with such things as they can find in very limited districts, little aware of what others may be doing in their own calling elsewhere. The diagram exhibited will show you the relative proportions of the annual mineral produce of the different European countries,* in nearly all of which, except Great Britain, mining schools are established, those states being fully aware of the effective researches they promote, and the waste of money they prevent. Are our miners less deserving of attention than those of other lands, or are they supposed so dull and disinclined to knowledge as not to be capable of profiting, as well as the miners of other nations, by instruction? Let those who thus believe visit our mining districts, espe-

* This diagram represented the mineral produce of the different European states by proportional lines. This produce is usually estimated as follows:—

Great Britain - -	1	Hartz - - - -	$\frac{1}{12}$
Russia and Poland - -	$\frac{2}{7}$	Tuscany - -	$\frac{1}{31}$
France - - -	$\frac{1}{4}$	Bavaria - - -	$\frac{1}{33}$
Austria - - -	$\frac{2}{13}$	Saxony - - -	$\frac{1}{34}$
Spain - - -	$\frac{1}{8}$	Piedmont and Savoy - -	$\frac{1}{38}$
Prussia - - - -	$\frac{1}{9}$	Denmark - - -	$\frac{1}{49}$
Sweden - - -	$\frac{2}{19}$	Norway - - -	$\frac{1}{55}$

cially such as are metalliferous, where the miner has so often to gain his daily bread by the exercise of his judgment, and they will speedily be undeceived. They will find men as able and willing to profit by instruction as elsewhere in our land. They will see many with powerful minds who have risen from amid all their difficulties, adding continually and greatly to our stock of practical knowledge, but who yet would evidently have accomplished far more, if, in their early day, they had possessed the advantage of starting with the knowledge of the time applicable to their pursuits. It is to be deplored that so much of the mass of important facts known to such men has been lost from the want of a system by which it could have been preserved for classification and use in further advance. Too much has perished with the remarkable men who have from time to time appeared in our mineral districts.

Seeing the large proportion of the mineral wealth of Europe furnished by the British Islands, it might, perhaps, be inferred from a superficial view of the subject, that a mining school, such as we propose opening this day, is useless. Very slight investigation will soon place this matter in its true light. The natural advantages, especially as regards the mode of occurrence and abundance of coal and of iron,—the cheapness and good qualities of which enable so many other industries to flourish,—are great in our land; iron and coal can be easily procured, worked, and retained for home use or exported, as may be thought advisable. These advantages are by no means possessed in like manner by other countries in Europe. Far from it; indeed, in several it is only by a most careful application of science and practice, and by seizing every discovery that can be turned to account, that profit can be effected. If the same indifference to general knowledge there existed as is permitted among us, the mineral produce of many of these states would be greatly diminished, and in some cases the mining in certain districts might even, to a great extent, be suspended, until new discoveries in science might enable successful operations to be carried on. For example, within the last three years, in Reichenstein, Silesia, certain mines, after remaining idle for five centuries, were, by a new method of Professor Plattner for obtaining gold from poor auriferous ores,

enabled to be again worked for gold, and with considerable profit.

Looking at our mineral produce, the great and chief mass is composed of our coal and iron. We raise the largest amount of both among the nations of the world; not that we possess the largest amount of coal in any land,—in this respect the United States of America far surpass us. The working of it, however, remains to be developed by them. The more need, therefore, that by skill on our part, and by not neglecting the application of knowledge which may bear upon it, we should not permit our advantages to escape. As regards fuel, what would man be without his power to produce and use fire? Remove this power, and what happens? How far could he range towards the colder regions of the earth, either as regards elevation in the atmosphere, or towards the poles? He must be a fire-making before he can be the cooking animal, which he is sometimes termed. Taken with iron, the great metal of civilization, his fire-making power is rendered immensely advantageous for his advance and well-being. Cheap heat and cheap iron are, therefore, among his important wants. While this country possesses the power to produce both, let not that power be wasted,—let science and practice be so combined, that the largest amount of both may be secured, and the future be regarded as well as the present.

The amount of coal annually raised in Great Britain (comparatively little is supplied by Ireland) is estimated at more than 35,000,000 tons. It probably much exceeds this amount; but taking that number of tons, 2,800,000 tons* being exported, 32,200,000 tons remain for household consumption, and for application to our various industries. London alone consumes nearly 3,500,000 tons of coal. No wonder we have a smoky metropolis.

With regard to iron, Great Britain has made remarkable progress within the last century. In 1750, only 30,000 tons of that metal were raised in it. In 1850, 2,250,000 tons of

* The quantity of coals, culm, and cinders exported in 1849 was 2,827,979 tons.

iron were produced. It is somewhat difficult, by means of official returns, to obtain the exact equivalent in tons of pig-iron exported, but we find the value of the iron export in 1849, including pig and bar iron, iron wire, and various kinds of wrought iron, taken at 4,245,049*l.** Iron, therefore, of many millions in value remains for our home consumption, applied in various ways to our national industry. Tin should not be omitted as among our important British metals, seeing that it is raised to the amount of about 400,000*l.* annually; neither should our copper be forgotten, since that of Cornwall and Devon alone may be valued at nearly 900,000*l.* annually. With regard to copper and tin in that district, (British tin is alone found there,) of the former it yields one-third, and of the latter nine-tenths of the whole supply from the remainder of the British islands and all the other countries of Europe. As to tin, the quantity taken from Cornwall and Devon from the time of the Phœnicians must have been enormous, seeing that until of late years it seems to have supplied nearly the whole of the European demand.

It has been mentioned that no institution existed, other than that we now propose to establish, in which the instruction so beneficial to our miners could be afforded. It, however, should not be forgotten that Sir Charles Lemon, ever alive to the progress and well-being of his native county, Cornwall, did, in 1838, establish at his own cost a mining school in it, being desirous of showing the importance of such an establishment. He continued this school for two or three years, and offered to place a considerable sum of money—10,000*l.*—at the disposal of the county, if it would add the like sum, to found a proper school of mines in Cornwall. Circumstances at the time prevented this important object from being carried out. There would, however, appear to be a movement in that district in the direction of such a school. Let us hope that it will continue, and be productive of a fitting establishment of the kind. There are also indications of the like movements in other mineral districts.

* This does not include steam engine machinery and mill work, the value of which, exported in 1849, is given as 709,071*l.*

May the endeavours of those who thus search to benefit our mining population by instruction be successful. The means of the greater numbers of that population will alone enable them to obtain instruction when brought to their doors. Surely it would not be over difficult, properly weighing all local conditions, to afford those who execute even the ordinary work teaching of an order which should be highly beneficial to them. How many lives would be saved in our collieries if but a fair range of information were afforded to those who too often have the lives of so many of their fellow-workmen in their power. In the examinations which have so frequently been instituted on the spot into the causes of explosions in our collieries, and in which I have had but too often personally to take a part, how constantly the frightful truth is forced upon us that folly and foolhardiness, founded on ignorance, have destroyed numbers, even to the amount of seventy and more, at one blast, and that every day hundreds of those who labour for our comfort or our profit are at the mercy of ignorance.

Let us hope that district instruction may soon commence, and that those who locally distinguish themselves by the application of their abilities may find in this institution, free of cost, the means of still further advancing themselves. Let opportunity be afforded to all for obtaining the knowledge which their course in life may require; shut out none from the chance of becoming pre-eminent. The history of the greatest discoveries teaches us, that it is not always by the rich that mankind have been advanced.

As far as may be in our power, we propose to explain by evening lectures to the working men of London, those really engaged in business, and whose good characters can be vouched for by their employers, such parts of our collections as may be thought to be usefully interesting to them. Some slight payment may be required, sufficient to prove that those attending desire to do so. At the time when our collections are open gratuitously to the public, the working man is usually engaged in his occupation; and yet to him we have much to show,—much that may be important to him in his calling. We trust therefore to aid him and consequently the public for whom he labours,

by endeavouring to convey instruction of the kind mentioned; an instruction which, as far as it may extend, those probably who have carefully considered the bearings of the late great Exhibition will not fail to view as an advance in the right direction.

In thus endeavouring to place before you, in a short address, some of the points which it appeared desirable to notice, I have felt so much embarrassment from the abundance of the riches at command, that in choosing subjects, many, perhaps, even of importance, may have been omitted. I pray you, therefore, carefully to examine the bearings of the subject by yourselves, feeling confident that you will come but to one conclusion, the necessity of the institution we inaugurate this day.

It will be the duty of my colleagues, charged with teaching the different branches of knowledge mentioned in our programme, each to point out, in an introductory discourse, the subjects which he may consider most worthy of attention in his science, whether viewed strictly as such, or in its application for the use and well-being of man.

It would be trespassing too far upon your time to occupy it with details and inferences which will be so much better laid before you by my colleagues. A few words, however, may not be out of place as to the useful applications of science generally, since the name borne by this institution really refers to several.

Geology, as now usually regarded, and as a whole, may be considered as a group of, at least, portions of different branches of knowledge, added to researches peculiar to itself, rather than as alone forming a science so distinct as to require only minor aid from others; this grouping, at the same time, presenting a most definite character, so that geology cannot be confounded with other branches of knowledge. In this, it may indeed, not very materially differ from some of those, once considered more separable from each other than modern discoveries will permit us now to view them; the mutual relations of several differently named sciences having been found greater, as a more profound knowledge of them has been obtained. Geology is, nevertheless, one among them, requiring such direct aid from several sciences, as to stand out somewhat

prominently, as is shown by the division of labour which has, of late, so much occupied the attention of its cultivators. Thus we have seen it requiring, and obtaining, the assistance of the mathematician, the astronomer, the physicist, the mechanician, the chemist, the mineralogist, the zoologist, and the botanist.

In applying such a branch of knowledge, it therefore, becomes important to view it as of a mixed kind requiring a corresponding system of instruction; its applications also requiring teaching in given directions, so as to embrace the conditions arising from the applications themselves. Hence the instruction proposed to be carried out at this institution is divided into various heads, so as to have reference not only to the miner and manufacturer, but also to the agriculturist, the architect, and the engineer, and so that the subjects taught should also be viewed in connexion with those arts to which they may be applicable.

In these days, when ocean steamers, railways, and electric telegraphs are transporting man, or his thought, from region to region, with a certainty and despatch not deemed probable even a few years since, and when a great Industrial Exhibition has just closed after a most brilliant career—an Exhibition which could not have existed without these and similar aids to the progress of mankind, it might appear superfluous to point to any applications, even those of the highest sciences, as contributing to the well-being of our kind. We still, however, too frequently hear of practical knowledge as if in a certain sense opposed to a scientific method of accounting for it, and as if experience, without that advantage, were more trustworthy than the like experience with it. Such may not, certainly, be the actual expressions; but the usual reasoning adopted, nevertheless, too frequently amounts to the same view.

Let it not for a moment, however, be inferred that we do not regard practical knowledge as of the highest importance, even in cases where those possessing it may not also possess the power of satisfactorily analysing it. Facts brought to light by practice are to general progress that which experiments are to experimental philosophy,—they have to be properly explained by the best methods at command, after they have been satisfactorily proved to be facts; a matter of no slight impor-

tance, seeing that so many things, so termed, are not such, We only desire that all interested should have the power to discriminate between sound and unsound views, so far as existing knowledge may be available,—taking all care not to neglect or depreciate the information afforded by those whose opportunities may not have sufficiently advanced their power to analyse and extend it. We should recollect how rapidly the science of our time has increased among the most instructed, and with it the power of its extension and application in directions not dreamt of by our forefathers. As some reason, right or wrong, is sure to be assigned for every practice, it is most important that those connected with it should possess the existing knowledge upon which it rests. It becomes a national duty to assist in collecting that knowledge for them, especially when widely scattered. For the purposes contemplated at this establishment, facts, bearing upon the teaching proposed, are to be sought far and wide, among various other nations as well as in our own. That there is an increasing feeling among those most interested, that successfully to apply a science requires both a knowledge of that science and of the subject to which it is to be applied, and that wherever there is a want for promoting the combined information it should be supplied, our every day experience shows.

Those whose duties or inclinations take them among our industrial population can scarcely fail to observe how much the term *practical* is becoming appreciated in its true sense. Indeed, the difficulties which the instructed in that population have to contend with from the uninstructed can scarcely otherwise than lead to correct views on this head. It is the duty of all to assist in affording to those whose minds are alive to every application of knowledge the power to acquire that which they are desirous of applying, so that they may possess the means of analysing their practice successfully for general progress and the public good. The more real knowledge is diffused, the more will effective practice be increased. Science and practice are not antagonistic, they are mutual aids. The one advances with the other. Civilization advances science, viewed in all its strictness and height; and science, by its applications,

advances civilization. Steadily bearing in mind these truths,—as we conceive them to be,—it will be our earnest endeavour at this institution to be useful, as far as our powers and abilities may permit, in promoting the progress of those for whom our teaching has especial reference; trusting, at the same time, to supply a national want, and, by so doing, assist in advancing the general good of our country.

The Study of Abstract Science essential to the Progress of Industry. (Being the Introductory Lecture to the Course of Chemistry.)

By Lyon Playfair, C.B., F.R.S.

The raw material used by Industry for the production of useful objects doubtless forms the basis of manufactures, but possesses a fluctuating value in relation to that of the object into which it is converted. In the successful prosecution of manufactures, apart from the influence of capital and labour, two elements are involved, each forming a factor which in a competition of Industry may be made to assume very different values. The first element is the raw material; the second, the skill and knowledge used in adapting it to the purposes for which it is designed. In America, cotton being indigenous, is cheap; and fuel, the other raw material employed in its conversion to a textile fabric, is not expensive. In England, the same cotton is much dearer, but the fuel may be assumed to be equal in price. The competition between the two countries, in respect to calico, resolves itself into the necessity that England, to overcome the disadvantage of the increased cost of the raw material, must infuse a greater amount of skill and knowledge into the processes employed in its adaptation to useful purposes. England has succeeded in doing this; and, consequently, the mills of Manchester may render unproductive the

Note.—Some years since, I gave a lecture, never published, though a few copies were printed for private circulation among my students, the subject being similar to this. A demand having been made for it by publishers, as expressive of a want now acknowledged by manufacturers to exist, I have preferred taking this opportunity to write a new lecture on the same text, incorporating some of the passages of the former lecture

mills of Lowell. But reverse the conditions of the two countries, and a similar result attests the truth of the same principle. Sheffield produces steel, which is exported in large quantity as a raw material to America. The history of that country has created a knowledge of the conditions required for the manufacture of edge-tools. The forests were not cleared, or the prairies converted into arable land, without that observing nation understanding the qualities and the requirements of the axe, the adze, and the spade. The knowledge thus attained was applied to the manufacture of edge-tools; and America returns to England its own steel, but under a new form, and endowed with an excellence, a temper, and a cheapness yet unattained by our artisans. Without this application of greater skill it would have been impossible for America to have competed with the country producing the raw material.

A nation, if it combine ordinary intelligence with its local advantages of cheap raw material, may long preserve almost a monopoly in special manufactures, and will continue to do so, either until the competing nation has risen so high above her in intelligence as to make this more than an equivalent for the local advantage of the other, or until a greater equalization in the price of the raw material renders a small amount of superiority in the intellectual element of sufficient importance to secure successful competition.

But should any great transition of the world take place by which local advantages were levelled, and the raw material confined to one country became readily attainable by all at a slight difference in its cost, then the competition in industry must become a competition in intellect; and the nation most quickly promoting the intellectual development of its artisans must, by an inevitable law of nature, advance; whilst the country neglecting its industrial training must as inevitably recede.

It requires no mental acumen to perceive that we are rapidly approaching to, if we have not yet arrived at, this period of wonderful transition, when nations must speedily acquire the levels due to their different amounts of intellectual development.

It is quite true that a superabundance of capital may for a time preserve a country from a quick depression, even should it lapse in its intellectual training; but the support thus given can only be temporary and illusory, for if, by the purchase of foreign talent, the necessary knowledge be infused into home manufactures, this can only have the effect of raising the intellectual element in the foreign country, and thus finally accelerate its success as a competing nation.

There never was a time when it was so necessary as now that skill and science should be united for the promotion of the industrial arts. At former periods of human history, local advantages or accidental combinations were the foundations of a nation's prosperity. The time is not distant when it was thought that the possession of mineral fuel indicated a country as the natural manufactory of the necessaries of life employing machinery for their production; while the existence of large tracts of land, warmed by a genial sun, stamped another nation as essentially agricultural, and employed its population in the labours of the field. Each country fell into a routine of manufacture; and Italy and France produced their silks and shawls, with as little thought of competition as England its machinery and calicoes.

Science in advancing has created resources unthought of before, and has removed the local barriers opposed to the progress of Industry. Countries were no longer confined in their aspirations by smallness of territory, for this by the aid of science enlarged its powers. The country able in its agricultural poverty to support only a scanty and miserable population, expanded itself for the reception of increased numbers as the produce of its land augmented, and thus knowledge, in the improvement of agriculture, won by a bloodless victory vast additional territory to aid in the industrial resources of the nation; for a land, with a twofold increase in agricultural production, has, for all practical purposes, unfolded itself to twice its size. Science in its progress was improving and simplifying processes of manufacture, while it was opening at the same time a communication between the nations of the earth. The amazing facilities of transport afforded by the introduction of steam

enabled a ready interchange of their natural riches; and mere adventitious local advantages, apart from skill and science in their adaptation, became of much less moment than they formerly were. The proof of this is in the fact, that the staple manufactures are now carried on in all parts of Europe, and that there is a constantly increasing and active competition of most of the great nations in all the markets of the world. If England still continue in advance, it will not be from the abundance of her coal and iron, but because, uniting science with practice, she enables her discoveries in philosophy to keep pace with her aptitude in applying them.

But is it true that England does act thus wisely; and is it true that science does hold in this country its just position in public esteem, or that it is fostered sufficiently to make that progress which it is now doing in other lands? To all such questions a negative reply must be given; for beyond a theoretical recognition of the importance of science in its relations to practice, and the establishment of this museum and college —a very important measure, I admit—the state and the public only look to the empirical result, and have not deemed it necessary to foster the knowledge producing it. But England is the only European state thus blind to its own interests, and not yet thoroughly awakened to the importance of giving an intellectual training to those intrusted with its manufactures. This is proved by the large endowments given by foreign governments for the support of institutions connected with Industrial Science, and it finds expression in the writings of their thinking men. "An equal appreciation of all parts of knowledge," says Humboldt, "is an especial requirement of the present epoch, in which the material wealth and the increasing prosperity of nations are in a great measure based on a more enlightened employment of natural products and forces. The most superficial glance at the present condition of European states shows, that those which linger in the race cannot hope to escape the partial diminution and perhaps the final annihilation of their resources. It is with nations as with nature, which, according to a happy expression of Goethe, knows no pause in ever-increasing movement, development, and production—a curse still cleaving to standing still.

"Nothing but serious occupation with Chemistry and natural and physical Science can defend a state from the consequences of competition. Man can produce no effect upon nature, or appropriate her powers, unless he is conversant with her laws, and with their relations to material objects according to measure and numbers. And in this lies the power of popular intelligence, which rises or falls as it encourages or neglects this study. Science and information are the joy and justification of mankind. They form the springs of a nation's wealth, being often indeed substitutes for those material riches which nature has in many cases distributed with so partial a hand. Those nations which remain behind in manufacturing activity, by neglecting the practical applications of the mechanical arts and of industrial Chemistry, to the transmission, growth, or manufacture of raw materials—those nations among whom respect for such activity does not pervade all classes—must inevitably fall from any prosperity they may have attained; and this by so much the more certainly and speedily as neighbouring states, instinct with the power of youthful renovation, in which Science and the arts of Industry operate or lend each other mutual assistance, are seen pressing forward in the race."

It is but the overflowings of science that thus enter into and animate industry. In its study we are never sure that the morrow may not gladden the world with an application of a principle to-day abstract, and apparently remote from practice. This is a truth above all things necessary to convert into a living faith the minds of those who devote their lives to its practical applications. Nothing is more erroneous in their case than to neglect the acquisition of abstract scientific truths because they appear remote from practice. I do not admit that it is even wise to address to oneself the question *cui bono?* Science is too lofty for measurement by the yard of utility;—too inestimable for expression by a money standard. These grovelling ideas of the objects of science, which constantly jar it in its intercourse with the world, ought to find no response in the breast of any devotee who would draw inspiration from its shrine. But whilst I protest against the indulgence of a mere utilitarian appetite for science, I think it infinitely advan-

tageous to examine it in its practical relations to life; but it must not be forgotten, that though the object of industrial study is to view science in its beneficent overflowings of kindness to man, these material benefits arise from the very fulness of its measure. If we revert back to the intellectual wanderings of science in its search for truth, it becomes surprising how soon it shook off the trammels of ignorance, and developed into a glorious liberty. Let us recollect how much science has advanced within the last three centuries, and even her past history becomes more remarkable in its progress than the present. It is no mean task for intellect to leap over the barriers of ignorance; it is even more easy to go onward in new and untrodden paths. It was only at the end of the sixteenth century that the Council of Sages at Salamanca negatived the idea of a western continent, by the writings of Lactantius. "Is there any one so foolish," says he, "as to believe that there are antipodes with their feet opposite to ours; people who walk with their heels upwards and their heads hanging down? That there is a part of the world in which all things are topsy-turvy; where the trees grow with their branches downwards, and where it rains, hails, and snows upwards?" Do we not know that Columbus was told by the Sages, that were he to succeed in sailing down the rotundity of the earth its bulging out would prevent him ever sailing up again; and do we not remember with what a stedfast faith in abstract truth he saw beyond "the region of the torrid zone, scorched by a blazing sun, a region of fire, where the very waves which beat upon the shores boiled under the intolerable fervour of the heavens?" Recollect that these were the opinions of a time when the utmost national encouragement was given to intellectual progress, and that it was not very many years after the death of Prince Henry of Portugal, who gave that glorious motto to princes, "the talent to do good." Recollect that this ignorance was manifested in the brightest time of the reign of the enlightened Isabella of Castile, and you will be surprised with me that science has since that time achieved what it has. Had Columbus not investigated the abstract truths of cosmography, the western continent, even with the advantage of the "astrolabe," discovered in his time, would perhaps for a century have re-

mained unknown. It is easy to make an egg stand on its end when the way is shown how to do it. The applications of science are not difficult, but without the science there are no applications. The philosophy of our times does not expend itself in furious discussions on mere scholastic trivialities, or unmeaning questions in theology. The scholastic learning of the middle ages was much confined to ecclesiastics, and it is not surprising to find both classical and theological literature engrafting itself upon the science of the time, and forcing it into the discussion of questions very foreign to its nature. It was a curious mixture of theology and science when the most learned men agitated themselves on subjects such as—the manner in which angels are nourished?—whether they usually speak Hebrew or Greek?—what are the spirits entrusted with the distribution of lightning and hail, and to which are confided the digestive powers of animals?—whether Adam, before the Fall, was acquainted with the *Liber Sententiarum* of Petrus Lombardus? The polemics of a past age do not represent the search after abstract truth of the present. Yet you are in no position even now to treat with derision the past errors of philosophy. The man who is on the mountain complains of the fog obstructing his view, while the inhabitant of the plain speaks of it as a cloud capping the mountain. Both are right, but read the phenomenon differently from each other. Yet only he that was in the fog could rightly appreciate its darkness, or fully understand the force of the rising sun that dissipated its obscurity. The progress of knowledge,—the search after truth,—can scarcely be recognized in its sublimity by those who do not understand the errors which had to be swept away before it could advance in an uninterrupted path.

There are very few instances in the history of science of a sudden development of great discoveries, either illumined from darkness by a flood of light from genius, or betrayed through some accidental and straggling ray. The growth of scientific discovery is slow; it does not, like the prophet's gourd, spring into full development in a single night. The great discoveries of science leave behind them no boundary line of demarcation from those which have preceded, but, like the full day succeeding

the dawning of the sun, follow that which fully foretold their approach. The telescope and microscope did not open their wonders to an unexpecting and startled world, but crept into existence with steps so slow that their impression is not sufficient to trace out the history of their progress. The improvements in the steam-engine were so gradual that a court of law, only half a century since, gave a solemn judgment that Watt had done nothing essential towards them. The compass cannot point to us the period when it offered its inestimable services to man, nor has paper left a record of its discoverer. In fact, all great practical discoveries are the result of much study, the exponent of a long series of observations, and often arise out of those truths of science which appeared least promising on their first announcement. Boyle knew that he wrote an imperishable truth when he titled his Essay "Man's great ignorance of the uses of Natural Things; or, that there is no one thing in Nature whereof the uses to Human Life are yet thoroughly understood." This truth of the seventeenth century is no less true in the nineteenth, the history of the intermediate time having been, as Sir John Herschel justly remarks, but one commentary on the text. The everyday progress of the arts abounds in new applications of objects the most familiar.

Practical, like abstract science, has no limits. The Romans thought themselves at the culminating point of civilization; and the Greeks, pluming themselves in their inventiveness, could not conceive that the world would ever take a higher flight. Even in our times, like opinions are entertained; because ignorance cannot see over the heights raised by modern science for a wider view of creation. These conceited ideas of a nation or of an age have no foundation. Science may see an horizon bounding her view; but as she proceeds onward the horizon constantly recedes, and shows the limit to be altogether illusory. In one time and generation a nation may, like Newton, pick up a few pebbles on the seashore, while the boundless ocean of science lies beyond, with all its vast and unexplored treasures.

Empiricism has frequently been a substitute for science; a lame and sluggish substitute, it is true, but nevertheless one

that in the history of mind has had much of influence. Gunpowder was known before the condensed air of which it consists was recognized or understood; and it succeeded in killing man, without a knowledge that man himself is little more than air similarly condensed. Man used and succeeded in producing condensed air in the form of food, without having the slightest conception of the character of the air out of which this wondrous transformation was effected. Without a knowledge of atmospheric pressure, mills and pumps were formed. Glass was produced from the ashes of the fern, and china from kaolin, without a knowledge of the principles involved in their production. The length of the year was known, and the duration of the seasons explained, without the law of gravitation being suspected. All this, it is true, arose without science, but required ages to grow into a stunted and feeble childhood; while no sooner did science remove the trammels of ignorance, than a few short years produced a vigorous manhood. Ignorance may grope in darkness on the confines of an unexplored region, but to proceed steadily and securely onwards she must borrow the lamp of science to guide her. Newton, "that glory to his species," as Chalmers calls him, did, by the exposition of the law of gravitation, produce more real practical benefits to industry than all the preceding ages of empiricism. Navigation and Commerce sprang from his time into a state of development formerly impossible; and every nation and every human being enjoys from him, and to the end of time will enjoy, actual material benefits which an eternity of empiricism could not have produced. The hard-won experience of two thousand years of the Chinese in regard to porcelain was given to the European by a few years applications of science. The improvements in postal communication, which allowed our kings to transmit a message to Edinburgh in five days, now enable us to send it in less time than their "post-haste messenger" could saddle his horse. But these, and other triumphs of mind over mere empirical experience, arose from a steady progress of abstract science, the practical applications appearing merely as offshoots. It is my chief object to show that abstract science is necessary to the development of

practice, and that it is above all things necessary to make it a part of the education of a man who is to devote his life to the progress of industry. There is no vein of science too abstract for future industrial application; none yet thoroughly mined out and exhausted. Volumes might be filled with illustrations of the practical benefits produced by the application of discoveries apparently the most unpromising in their origin; but a few only can be selected in support of the text of my argument.

The most "practical" man,—a title erroneously used by our English to envelope their ignorance,—could not have objected to the marvellous development of truth arising from the study of light, that messenger from the sun sent at the rate of 180,000 miles in a second, to illumine our earth with the glory of its parent. It was wondrous to be told that the light of yonder far-distant fixed star, travelling without cessation at the same incredible speed, and which has this night struck our wondering eyes, started in its long and weary course some billions of years since, and has now for the first time shed its pale light on such points in time and space as ourselves. The sublimity of these truths awes the utilitarian, and hushes his half-uttered question of *cui bono?* But show him a young officer of artillery looking through a prism at the windows of the palace of the Luxembourg, and noticing that, in a particular position, the light of these windows disappeared from his view—show him, further, the startled wonder with which the philosophers of Europe heard of this phenomenon, and the eagerness with which they threw themselves into the track of an observation apparently so insignificant,—and your utilitarian sneers at science and its followers, and buries himself again in the darkness of his empiricism. The light reflected from the palace of the Luxembourg had suffered a change similar to that experienced by ordinary light in passing through doubly refracting Iceland spar. When a ray of this changed or *polarized* light is passed through plates of crystallized substances, brilliant colours and a peculiar structure are observed. These remarkable phenomena were indeed well worthy of the attention of scientific observers. Nothing, however, could

appear more remote from practice than the study of an altered beam of light. It was most interesting that, as in the case of sound, where two sounds reaching the ear either exalt or destroy the effect, so, in light, two rays interfering with each other may produce darkness. Much of the light from reflecting surfaces was found to possess this changed condition. The light coming from the surface of water being thus altered, refuses to pass through a "Nicolls' prism" in a particular direction. If, therefore, you look at the shadow of a man on a smooth lake, on turning round the prism the shadow disappears, while the man, seen by common light, remains visible. The story of Peter Schlimmel is thus realised. But who, from these curious observations, would have dreamt that out of them would come useful applications?

In a short time, however, this property of the polarizing prism was applied to the important purpose of detecting rocks and shoals at sea. It had long been the practice of mariners, when they suspected the existence of shoals, to look out for them at the masthead, because the outlook from his vertical position shut out much of the light that dazzled and obstructed his view. But as part of this dazzling reflected light is polarized, it is obvious that the polarizing prism enables the observer to scan the depths of the ocean, uninterrupted by its glare. Behold then the light which struck the student's eye when gazing on the Luxembourg used to preserve man from the hazards of the sea. It was easy to apply it in new directions; and the salmon-fisher speared fish at depths inaccessible to his unaided vision; while the engineer used its searching powers to discover the laws of tension in beams. Mechanics and Chemistry both pressed it to further their resources. Under the hands of a Biot, a ray of polarized light performed with magical quickness the most refined but tedious operations of the analytical chemist, and enabled him to tell the amount of sugar in the cane or beet juice. He thus followed the increasing richness of sugar in the juices of various plants at different stages of their growth, and was enabled to suggest a more economical adaptation of the labour applied to their cultivation. Thus, when beet is ready to be gathered, labour is in demand for the harvesting of other

crops, and consequently is expensive. It would not then do to take another crop, such as parsnips, inferior in its amount of sugar, as the cost of production would outweigh the return; but when the horses and carts are disengaged, and labour is cheap, parsnips are richest in their amount of sugar, and the idle mills may be usefully employed in producing sugar from this plant. By the same ray of light the size of distant objects may be measured, and even time may record its passage. This latter application, made by Wheatstone, is especially remarkable, and gives a means more accurate and useful than the sun-dial of determining the apparent solar time by the diurnal changes of the plane of polarization at the north pole of the sky. By availing himself of the fact, that the planes of polarization in the north pole of the sky change exactly as the position of the hour circle alters, he has adapted a simple and ingenious apparatus, by which the true time may be told within three minutes. All these are strange paths to practice, opened out by a ray accidentally caught in its passage from a window of the Luxembourg. Pass from its utilitarianism to its unfolding of nature's laws, and follow the same straggling ray, as it silently displays its gorgeous colours while passing through a transparent mineral substance, until it gives to man the knowledge as to whether the light of the sun proceeds from its solid mass or from its gaseous canopy, or whether comets enjoy light of their own, or borrow it by reflection from other bodies.

I now pass to light in its ordinary form, and ask you to examine the importance of studying its abstract phenomena. The world had long known that salts of silver were blackened by exposure to light; and the fact became familiar by their use as cauteries, or as indelible inks for linen, Wedgwood proposed to apply this means to fix the fleeting pictures of the camera obscura; but the results of his experiments being imperfect, the suggestion itself was almost forgotten. In the meantime chemists pursued their abstract discoveries, and without relation to this want investigated the properties of gallic acid, and of the iodide of bromine, and found a class of salts termed the hyposulphites. Some of these bodies pos-

sessed properties accelerating the blackening of silver salts by light; the others prevent the further blackening when applied. Philosophers began now to revert to the old idea, for truth is never lost, though its reality may be incapable of proof at a given time; and thus various unconnected discoveries began to re-act one upon the other, until man was able to use the Sun as the painter of the pictures exhibited and enlivened by his glory. So perfect became the art, by new adaptations of other discoveries, that the most fleeting objects can be depicted. The flash of lightning exhibits its fiery streak on these sun-painted pictures. The tossing out of lavas, the vomiting forth of smoke, and the bellowing of flame from craters in their wildest moods, are pourtrayed with unerring fidelity; the tumultuous dashing of the cataract and the slight rippling of the stream, the changing forms of the clouds, the sparkling of the rain-drop, and the ever-varying expresssion of the human countenance, are all capable of being preserved in these paintings by nature. Nay the truthfulness of the sun-painted landscape is so great that from the very shadows of the picture the altitude of the sun may be determined; and the time at which it was taken being known, the latitude of the locality may be elicited. Artists now use this application of light to acquire models for study; and the engineer employs it to obtain proofs of the exact state and progress of the works superintended by him. Doubtless very soon, for it is now all but accomplished, the Sun will be compelled to fix those transitory coloured glories which he now imparts to natural objects; but not till then should man cease to question him as to the means of accomplishing this end. I need not say that this art is but disclosing its future applications. Already can we use the sun to record observations too delicate for man's perception. The constant and momentary excursions of the magnet, the ever-recurring variations of the thermometer and barometer, are now recorded by light with a fidelity and precision unattainable by the most conscientious and unremitting observers.

These instances will suffice to show that the study of abstract laws, so far as regards light, produces as offshoots important practical applications; and in each department of science, like

lessons may be taught. There never was an age so rich in practical applications as that in which we live, and it is interesting to see them drawn from truths long familiar to man, and apparently beyond the range of utilitarian application. When an Italian physician, having hung on an iron railing the legs of a frog fastened to copper hooks, observed that each gust of wind caused convulsions in the legs of the dead animal, who could have prophesied that this observation would entirely alter the character of a future century? and yet it is but an application of this discovery, extended, it is true, by many intermediate researches, that annihilates space and time,—that empowers our thought to travel with the speed and with the power of lightning to the most distant land, and enables mind to be reciprocated without being arrested by distance in space. Who could have dreamt that the same discovery of Galvani would in future join continents, in spite of intervening seas, and give more security to nations than cordons of soldiers or fleets at sea, by rendering sudden invasion all but impossible? At the late Exhibition you had a singular proof of this quick interchange of intelligence, for every morning you could buy at a trifling cost a map showing the state of the wind, of the barometer and thermometer, in all the principal towns in Great Britain during the previous day. You have already seen how useful may be made this discovery; for a transit of a star at Greenwich and at Paris may be instantaneously recorded, and their respective longitudes verified. As a means of communicating intelligence, its powers are not yet nearly developed; for in its mercantile communications it produces consequences no less individually important than its general results, such as when it sends information to distant provinces of the approach of a tornado, time being thus given to provide against the fury of the storm. It is rare indeed that brilliant discoveries, such as the electric telegraph,* flash matured across a human intellect, and in a generation produce such mighty results. It is true

* The electric telegraph, as now used, is a *discovery* in science, and not a mere application or *invention;* for it was a most important discovery that the earth itself could be used as part of the circuit.

that some of the most wonderful discoveries have been shadowed forth by a sudden inspiration; but in few cases has that shadow appeared as a picture with all its lights and shades. Before steam had been subjugated to the service of man, in accelerating his transit on land or water, Darwin had said,

> "Soon shall thine arm, unconquered steam, afar
> Drag the slow barge, or move the rapid car."

By a similar prophetic spirit, resulting, however, partly from induction, Goethe saw that the parts of flowers are metamorphosed leaves, and Oken, when stumbling over a bleached skull, perceived that the osseous system was constructed on the vertebral type. But it was only by patient and long-continued study that these thoughts became substantive realities. This is essentially the case in electricity, which is but now beginning to reward mankind at large for all the patient investigations of the philosopher. Already has the fierce and untamed lightning allowed itself to be dragged from its course, and be conducted tranquilly to places where its fury is dissipated without injury to man. Even in its fiery flashings in the wide expanse of the ocean, it submits to the intellect of a Franklin, and leaves unscathed the ship rolling on the stormy waves. Providence, in His beneficence to man, has allowed him to find "a way for the lightning of thunder." Artificially formed, it allows itself to be conducted through land and sea, humbly serving the purposes of man, by blowing up mines, or enabling him to rescue treasures from sunken vessels.

This immaterial power produces material results at places fixed on by the will of man; and London may now fire a friendly salute at the Invalides, while Paris returns the compliment with the guns of the Tower. Although, as yet, electricity is not used with economy as a motive power, the obstacle is only in the cost; and even this may be resolved as discoveries progress.

Although her passage is so rapid that a journey to Paris can scarcely be expressed in time, yet she may be controlled, and used to record time's own progress; for nothing is more accurate than clocks worked by her power. It would not be difficult

to have all the clocks in a town worked with perfect uniformity by the aid of electricity.

Electricity now plates with gold and silver the baser metals; copies in metal from more perishable materials the most exquisite designs and forms; perpetuates the skill of the engraver, by multiplying, at a trifling cost, his elaborately engraved plates; and separates and purifies the metals, formerly only obtainable by tedious and complex chemical operations.

Electricity offers for your lighthouses light of a brilliancy the most intense, and asks you to substitute the light gas which streams through the streets by a still more ethereal existence, running along simple wires.

Even in the smallest offices of good-will to man she refuses not her aid, and offers to tell the perfumer whether his essential oils are adulterated with cheaper fatty substances, as willingly as she lends aid to the Chemist in the minute operations of his laboratory practice, or as she kindly ministers with the Physician to allay human suffering and restore wasted strength. Recollect, that all these are but the beginning of her applications, and that we know not to what extent they may be carried out; and rejoice with me that philosophers studied her abstract laws, from the knowledge of which these applications have arisen.

I have no time to extract further examples from physics or meteorology, but I cannot refrain from directing a passing glance at the beautiful discoveries of Colonel Sir William Reid. Studying the phenomena of a hurricane at Barbadoes, he followed out his observations to all recorded hurricanes, and thus elicited the simple law that hurricanes and many gales are progressive whirlwinds, revolving in the direction of the hands of a watch in the southern, and in the reverse direction in the northern hemisphere, but moving along in its mass at the same time. The variable winds in a hurricane now become intelligible, and a mariner caught by it may use every wind to steer out of its course, and prevent himself being overwhelmed in its vortex. To be wrecked in a hurricane, with an open sea, can now only result from a lamentable ignorance of scientific laws; for knowledge has triumphed over the terrors of the storm.

Let us now turn to Chemistry proper, and see how this supports the text of the argument. It is an old science, and from the time of Tubal Cain to that of Liebig has been progressing steadily onwards, though not always with similar aims and aspirations. The alchemists erred, as England now errs, by valuing and studying only practical applications, instead of following abstract laws. Health, wealth, and longevity comprised their aspirations, in the place of eternal truth. But these objects were sufficiently important to produce in their search "a zeal allied to madness," and facts became accumulated of infinite importance to the science when it attained self-consciousness, and learned to value itself for its nobler ends.

No later than the time of Henry IV., a royal edict recommended that "the clergy should search for the philosopher's stone, for since they can change bread and wine into the body and blood of Christ, they must also, by the help of God, succeed in transmuting the baser metals into gold."

As soon as Chemistry began to be studied for the mere sake of abstract truth, then she deigned to reward man for his unselfishness by numerous collateral results having a direct material benefit.

He who supposes that Chemistry is the result of practical knowledge derived in its contact with industry knows little of the progress of the human mind, or is little grateful for the infinite development which it has given to human resources and human enjoyment. Let us select a few examples of abstract chemical truths bearing on practical appliances. I will first refer to the Miners Safety Lamp as a most important example of an industrial result depending upon pure induction from abstract science. An element of destruction, apparently uncontrollable by human power, had to be subjugated so completely as to be put under the management of the most uneducated miner. More dreadful in its effects than those of the lightning and the earthquake, fire damp, the scourge of the miner, seemed to defy investigation even as a scientific phenomenon. By a pure inductive method, such as a Bacon would have loved to witness, Davy traced its history, step by step, until he fully made out all its characters. He discovered that it in reality requires a very high heat for ignition, the temperature of red-

hot iron or charcoal being insufficient to inflame it. The gas was found not to explode in narrow tubes, as these cool it below the point of ignition; and a network of iron wire is only a series of sectional tubes. A lamp surrounded by wire gauze is now constructed, and this allows a light to be carried into the most dangerous mine with perfect safety. What a wonderful discovery is this! The destructive gnome of the mine is imprisoned within a cage of mere wire gauze, and, vainly struggling to escape, heats to redness the bars of its prison. Science, to its glory, has destroyed those scenes of death and heart-sickening misery which haunted the miner in his most peaceful hours, and has rendered safe an occupation formerly one of dread and danger.

When Dumas investigated the laws of substitution, and discovered a new body by distilling alcohol with bleaching powder, interesting indeed in its chemical formula, but capable of being sneered at by those who see science at a distance, by a wrong-end telescopic view of its commercial productiveness; who could have dreamt that this *chloroform* was destined to remove many of the woes which man is heir to, by mitigating pain, and preventing its occurrence even in the most severe surgical operations?

In 1842, I had the pleasure of travelling with the Dean of Westminster and Liebig over different parts of England. Among other places we visited a limestone in the neighbourhood of Clifton, where in former times saurian reptiles had been the pirates of the sea. There, along with the relics of the fishes on which they had preyed, were their own animal remains. Coprolites existed in great abundance, and proved the extraordinary number of the reptiles which must have existed. The interesting question arose as to whether these excretions of extinct animals contained the mineral ingredients of so much value in animal manure. The question was in fact not yet solved by the chemist, and we took specimens, in order to confirm by chemical analysis the views of the geologist. After Liebig had completed their analysis, he saw that they might be made applicable to practical purposes. "What a curious and interesting subject for contemplation! In the remains of an extinct *animal* world England is to find the means of increasing her wealth in agri-

cultural produce, as she has already found the great support of her manufacturing industry in fossil fuel—the preserved matter of primeval forests—the remains of a vegetable world! May this expectation be realised! and may her excellent population be thus redeemed from poverty and misery!" I well recollect the storm of ridicule raised by these expressions of the German philosopher, and yet truth has triumphed over scepticism, and thousands of tons of similar animal remains are now used in promoting the fertility of our fields. The geological observer, in his search after evidences of ancient life, aided by the chemist, excavated extinct remains which produced new life to future generations.

Two years before this, the same German philosopher, in his researches into the food of plants, had drawn attention to the importance of guano as a manure, and by his intellect wafted fleets to the Ichaboes and to the Incas.

Man gets so accustomed to luxurious applications of science, that he often forgets the searcher of abstract truth whose discoveries led to them. Nothing is more useful than has been the discovery of the lucifer match. Some of us recollect the time when the tinder-box was the only artificial means of procuring light, and a lively remembrance of the often-unsuccessful efforts, always tedious and lengthy, is required fully to appreciate the value of the lucifer match. What an improvement it was when a little bottle of oil of vitriol could be carried about, and by dipping matches into this, light was obtained! And yet this elegant method is now considered clumsy, and is entirely superseded in less than ten years. The properties of chlorate of potash and of phosphorus became by study better understood, and their application to the production of artificial light was apparently perfected. But the lucifer match maker is dangerous to society, and a curse to himself. The transparent waxy phosphorus with which he works must always be kept under water, and even then is so hazardous that insurance offices decline to insure the premises in which it is contained. The heat of the hand causes it to inflame, and the worker, even avoiding this, becomes diseased and liable to ulcers. The practical man now helplessly lays his wants

before the searcher of abstract truth. Chemists had for some time noticed that various bodies assume different forms, as, for example, carbon, in the states of diamond, graphite, and charcoal. An Austrian chemist, Professor Schrötter, investigating the abstract laws of allatropism, inquires whether phosphorus has more than one form, and by heat changes the transparent wax into a scarlet body. This scarlet substance is the same phosphorus, but in a state in which it may be kept in the open air, or packed up and transported in casks, and is not readily inflamed by a gentle heat or by friction. Physiologically it has little action on the body, and yet by proper admixtures makes as good lucifer matches as the ordinary dangerous phosphorus. By these discoveries the means of giving artificial light is rendered a safe and healthy manufacture.

A French chemist discovers that paper immersed in nitric acid unites with that body, and becomes highly combustible. Any woody fibre is subsequently found to do the same. This observation lies dormant for years, noticed only as an interesting fact, under a long and scientific term, in the books of chemists. But one day a Swiss chemist announces the startling fact, that the peaceful cotton bales of Manchester may be converted into dangerous ammunition of war, and that cotton unchanged in its physical appearance has been made more destructive than gunpowder. There was something appalling in the fact of this peaceful representative of industry being made to assume such destructive properties, under the magic wand of the chemist. The chemist now examines cotton in the new form, and trying to purify it, finds that it is soluble in ether. When left exposed, the ether quickly evaporates, and the gun-cotton retains a skin-like appearance. Surgeons seize the discovery of the chemist, and gun-cotton dissolved can heal the wounds it makes in its dry state. Numerous applications follow, and man, forgetting his fear, uses the gun-cotton to silver mirrors, and to produce the portraits of his friends on glass, by a process speedy as the Daguerreotype. Another chemist, seeing how readily cotton unites with acids, investigates its power of combining with alkalies. He discovers that it does so, but notices that a contraction ensues in its fibres. Looms are not now required to

make coarse calico fine, for immersion in soda makes it take the form of fine cambric. The alkaline calico washed in water loses its soda, but unites with water, and this in turn is displaced by colours when the calico is dyed, so that the calico assumes dyes of much greater intensity and brilliancy.

Analogous to this is the application of a well-known fact to the manufacture of flax cotton. As long ago as the time of Solomon, it was well known that acids produce an effervescence with carbonate of soda, for that wise King says, singing songs to a heavy heart is like pouring vinegar upon natron (mis-translated nitre). This old fact is now used to separate the fibres of flax, and give to it a cotton-looking appearance and properties. But this would have been insufficient as a practical result, had it not been that scientific discoveries had shown the existence of a class of bleaching compounds, termed hypochlorites, which enable a few hours to do the work of many weeks.

These various discoveries of Schonbein, Mercer, and others, did not in any case arise from a direct practical search, but as offshoots of abstract investigation.

Antioch, in the beginning of the fourth century, discovered the importance, as a matter of police, of lighting its streets. But the discovery lapsed, and it was only in the middle of the sixteenth century that Paris lighted up her streets by fires made of pitch and rosin. Slowly did this matter of primary police creep on till the end of the last century, when it started forward with extraordinary vigour. Chemists had long observed that coal on being distilled produced a combustible gas, and the means of collecting and distributing various kinds of gas were among the common experiments of a lecture table. But it was not till 1792 that Murdoch employed coal gas to light up his offices at Redruth. Now gas has entirely substituted oil in the lighting of streets, but simply as a question of cost, the coals from which it is produced being cheaper than the corn necessary to form tallow. It by no means follows that gas is always the most convenient form of using a combustible. "It would certainly," says Liebig, "be considered one of the greatest discoveries of the age if any one could succeed in condensing coal gas into a white, dry, solid, odourless substance, portable, and capable of being placed upon a candlestick or burned in a lamp." A want

is rarely clearly expressed by man that science does not administer to it; and already is the desire of Liebig accomplished. A mineral oil flowed out of coal in Derbyshire, and was obviously produced by a slow process of distillation from the coal. It contained solid paraffine dissolved in a liquid oil. Mr. Young, of Manchester, in examining the mode of its formation, found that paraffine, a solid waxy substance hitherto never produced from coal, could in reality be readily formed in commercial quantities by a slow and regular distillation. This, in fact, is "condensed coal gas," or, rather, it might be considered as a solid form of olefiant gas. It is therefore really the want of Liebig supplied. In forming coke, this product, dissolved in an oil of a similar composition, may readily be obtained; and useful products are made instead of those waste gases now thrown uselessly into the atmosphere. It might appear chimerical to you if I were to state many of the consequences which must follow if this discovery in its maturity be found as successful as it promises to be in its dawn; but it is not difficult to see that a cheaper and less carbonised coke could be burned in our domestic fires; and thus we might see a sun which now refuses to penetrate the sooty canopy of our cities.

Hour after hour might be employed in recording the triumphs of chemistry in its investigations into the play of the organic elements. Looking back no further than the last few years, you see how it has thrown open the most hidden processes of animal and vegetable life; how it has taught us to increase and economise the food of man. It is even yet the practice of those who have not followed her discoveries into the wondrous affinities of the few simple organic elements to depreciate the importance of following their infinite creations. If, however, there were no other result from doing so than the one great achievement of having explained the ingredients in food used to build up the muscular frame and those employed in the support of animal heat, the importance of that discovery would have repaid all the labour of the past century.

Almost all the staple manufactures of this country are founded on chemical principles, a knowledge of which is absolutely indispensable for their economical application. In a few educational establishments and in some of our universities the alphabet

of chemical science is taught; but it requires an institution such as this, devoted to a special object, to teach how to use that alphabet in reading manufactures. The extension of scientific and technical education is a want of the age. The old and yet widely-existing scholastic system of education introduced by the revival of learning in the fourteenth and fifteenth centuries is ill adapted to the necessities of the times. Erasmus would not now aid Cambridge in advancing the progress of England, nor would Vitelli make Oxford useful to the mass of its population. It would be of little use to the lagging progress of Italy even if Chrysoloras were again to teach Greek in its universities. Euripides and Thucydides cannot make power looms and spinning-jennies; for these Watts and Arkwrights are required. A Poggio may discover copies of Lucretius and Quintilian, without thereby producing a result equal to that of the smallest inventions of a Stephenson or a Wheatstone. When will our schools learn that dead literature cannot be the parent of living science or of active industry? I do not underrate classical learning as an elegant accomplishment, or as a branch of human knowledge; I can rejoice as much in a good thought from Plato, or a happy allusion from Aristophanes, as I can in hearing a discussion on the philological affinities of the Indo-Germanic tongues; but I cannot understand why our sons of industry, destined to reap its harvests, should be placed in its fields of corn, having only been taught how to cull the poppies. "The great desideratum of the present age," says Liebig, "is practically manifested in the establishment of schools in which the natural sciences occupy the most prominent places in the course of instruction. From these schools a more vigorous generation will come forth, powerful in understanding, qualified to appreciate and to accomplish all that is truly great, and to bring forth fruits of universal usefulness. Through them the resources, the wealth, and the strength of empires will be incalculably increased."

Institutions, such as this, are not substitutes for, but supplements to, the universities. It is the industrial training which we profess, and everything else is made subsidiary to that object. Not that we do or should forget abstract science, as such, because I believe the discoveries in abstract laws are of more

real benefit to industry than their immediate applications. The technical man is, perhaps, of more use to himself and to his time and generation than he who discovers the abstract laws applied by the former to the purposes of industry; but it is the abstract philosopher who benefits all time, and confers universal and eternal benefit to society.

If I have convinced you that it is of infinite importance to a nation, not only to study science as constituting the foundation on which industry rests, but to promote the advancement of abstract science, the soul and life of industry, you will readily understand the importance of institutions the object of which is to infuse this life into special departments of technology. England has too long rested on the position which it has acquired as a manufacturing nation. This position was gained when local advantages gave an impulse to our practical national mind. But now that the progress of human events has converted the competition of industry into a competition of intellect, it will no longer do to plume and pride ourselves on our power of mere practical adaptations. It is miserable to see our industrial population glorying in their ignorance of the principles on which their manufactures depend, and vaunting their empiricism, or, as they term it, their "practice." Let us waken from this delusion, unless we prefer to—

> "Sit like spent and patient fools,
> Still puffing in the dark at one poor coal,
> Held on by hope till the last spark is out."

If England keep pace with other countries as a manufacturing nation, it must be by her sons of industry becoming humble disciples of science. At present her reliance in the "practical" or "common sense" of her population is the sunken rock directly in the course both of her agriculture and manufactures. On this subject Archbishop Whately has some excellent remarks. "By common sense," says he, "is meant, I apprehend (when the term is used with any distinct meaning), an exercise of judgment, unaided by any art or system of rules; such an exercise as we must necessarily employ in numberless cases of daily occurrence, in which, having no established principles to guide us, no line of procedure, as it were, distinctly chalked out, we must needs act on the best extemporaneous

conjectures we can form. He who is eminently successful in doing this is said to possess a superior degree of common sense. But that common sense is only our *second best* guide,—that the rules of art, if judiciously framed, are always desirable when they can be had,—is an assertion for which I may appeal to the testimony of mankind in general, which is so much the more valuable, inasmuch as it may be accounted the testimony of *adversaries;* for the generality have a strong predilection in favour of common sense, except in those points in which they respectively possess the knowledge of a system of rules, but in these points they deride any one who trusts to unaided common sense. A sailor, e. g., will perhaps despise the pretensions of medical men, and prefer treating a disease by common sense; but he would ridicule the proposal of navigating a ship by common sense, without regard to the maxims of nautical art. A physician again will perhaps contemn systems of political economy, of logic, or metaphysics, and insist on the superior wisdom of trusting to common sense on such matters; but he would never approve of trusting to common sense in the treatment of diseases. Neither, again, would the architect recommend a reliance on common sense alone in building, nor the musician in music, to the neglect of those systems of rules, which, in their respective arts, have been deduced from scientific reasoning, aided by experience; and the induction might be extended to every department of practice. Since, therefore, each gives the preference to unassisted common sense only in those cases where he himself has nothing else to trust to, and invariably resorts to the rules of art wherever he possesses the knowledge of them, it is plain that mankind bear their testimony, though unconsciously, and often unwillingly, to the preference of systematic knowledge to conjectural judgments." Practice and science must now join together in a solemn union, or the former will soon emigrate to other lands. The time is past when practice can go on in the blind and vain confidence of a shallow empiricism, severed from science "like a tree from its roots." The rudest sailor may steer his ship in the direction of a landmark, but without compass and sextant he dare not traverse the expanse of ocean. Ignorance may walk in the path dimly lighted by advancing knowledge, but she

stands in dismay when science passes her; and she is unable to follow, like the foolish virgin having no oil in her lamp. Depend upon it, an empirical knowledge of practice is not the way now to succeed in the struggle of individuals, or in the struggle of nations. Intellect is on the stretch to get forward, and that nation which holds not by it will soon be left behind. For a long time, practice, standing still in the pride of empiricism, and in the ungrateful forgetfulness of what science has done in its development, reared upon its portal the old and vulgar adage, "an ounce of practice is worth a ton of theory." This wretched inscription acted like a Gorgon's head, and turned to stone the aspirations of science. Believe it not! for a grain of theory, if that be an expression for science, will, when planted, like the mustard seed of Scripture, grow and wax into the greatest of trees. The pressure and difficulties of the age, and the rapid advancement of intellect in continental nations, have been the Perseus to cut off this Medusa's head from the industry of England, and to fix it on the shield of Minerva, who turns to stone such as still believe that science should be ignored by practice; but, reversing that shield, wisely conducts those who would go further under her guidance. It is now rare to find men who openly avow, although they actually entertain, a belief in a necessary antagonism between theory and practice. Theory is in fact the rule, and practice its example. Theory is but the attempt to furnish an intelligent explanation of what is empirically ascertained to be true, and is always useful, even when wrong. Theories are the leaves of the tree of science, drawing nutriment to the parent stem while they last, and by their fall and decay affording the materials for the new leaves which are to succeed.

I have now said enough to show you that it is indispensable for this country to have a scientific education in connexion with manufactures, if we wish to outstrip the intellectual competition which now, happily for the world, prevails in all departments of industry. As surely as darkness follows the setting of the sun, so surely will England recede as a manufacturing nation, unless her industrial population become much more conversant with science than they now are.

The Relations of Natural History to Geology and the Arts. (A Lecture Introductory to the Course to be delivered during the Session 1851–1852.)

By Edward Forbes, F.R.S.

Natural History is a vast and continually extending science. It embraces Zoology, Botany, and much of Geology. The sections of it are subdivided into studies, each of which, if pursued to its full development, would more than occupy a lifetime. No single man can, in the present state of knowledge, grasp the details of all the natural history sciences, or even of one of their great sections. But the principles that pervade all are the same. The same laws govern the animal and vegetable kingdoms. The same laws regulated the phenomena of animal and vegetable life through the geological past that now regulate them in the historical present. That such is true is for the naturalist to demonstrate. The zoologist, the botanist, and the geologist contribute the elements of the demonstration, but the great pervading principles of the entire science demand a combined study of the three kingdoms of nature. The task assigned to me in this Institution is the exposition of these principles; their illustration by examples drawn from existing and extinct forms of life; and the teaching of such details of zoology and botany, recent and fossil, as are necessary to the accurate conduct of geological research, and have thereby a practical and economic bearing, through the certainty they give to geological determinations. A second and distinct duty, hereafter to be performed, will be the illustration of the application of natural history knowledge to the arts and manufactures.

Of all the departments of the educational system adopted in this Institution, mine is apparently the least practical. The chemist, the metallurgist, the mechanician, come directly into contact with the arts and their votaries. The miner furnishes the materials from which so much of the riches of England is derived. The geologist investigates the structure of the country, and thus gives certainty to the operations of the engineer, developes new sources of mineral and agricultural wealth, and prevents the expenditure of capital in wrong directions. All men understand why the manufacturer and artizan are indebted to the chemist and metallurgist, whose obligations to the miner and the geologist are too evident not to be freely acknowledged by themselves and those who benefit by their pursuits. But the naturalist seems to work apart from practical men. His duties are performed behind the scenes, and make no conspicuous show. His share in the work can be fully appreciated only by the geologist, whose requirements necessarily lead him into the palæontological laboratories. Like a labourer among the foundations of an edifice, he is unseen by the crowd who admire the beautiful superstructure, though without his labour the building would be unsafe and incomplete. It needs but a brief argument to prove this to an intelligent audience.

That geology is an essential element of a scientific mining education is obvious at first thought. That natural history should be, may not seem so evident to persons as yet unversed in geology. That palæontology is an essential element of geological science, no one who is acquainted with the rules by which the relative ages of sedimentary rocks are determined will deny. And that palæontology, apart from natural history, is empirical and false, and has no claims to the dignified title of science, every intelligent student of organic remains will maintain. Therefore, the teaching of the study of fossils in this Institution is to be conducted with constant reference to and comparison with living organisms; 'for by no other method can we hope to gain an insight into the history of the manifestations of life during the geological past, such as is necessary for the truly scientific, and, consequently, *safely practical* study of geological science and its applications.

The value of natural history as an educational science has been but partially recognized in Britain. In our schools and colleges, the chief cultivation has been directed to the nurture and training of the memory, the reasoning powers, and taste; not always by the most judicious methods. Observation, a faculty upon the correct exercise of which the value of the others in a great measure must depend, has been neglected or even entirely ignored. Yet to observe truly, to note accurately, are surely qualities of essential importance to the well-being and future prospects of every youth. The successful progress of a man through life, the weight attached to his statements, must, in a great measure, depend upon them. The simplest, easiest, and most beneficial method of cultivating the observing powers lies in the acquirement of the methods and practice of the natural history sciences. Ignorance alone could have excluded them from recognized courses of education. Though partly taught in some of our Universities, it is as branches of knowledge usually in connexion with the enlightened profession of medicine, and not on account of their value in educational training. Of late, however, there has been a tendency to rectify this. Oxford and Cambridge have recognized, in theory at least, the right of natural history to share in their honours. Their younger sister, London, with the timidity of youth, has hesitated to pronounce in its favour. In the metropolitan colleges, and the universities of Scotland and Ireland, the natural history sciences are taught by able professors; but the total number of their unprofessional disciples is small, and cannot be said to be increasing. In schools of lesser grade they assume, when professed to be taught at all, the form of intellectual recreations; not that of exercises, and strengtheners of the mind of the pupil. The time, I trust, will yet come when every student will be required to educate his observing powers through the agency of these delightful branches of study.

The earliest efforts of infant intellect are directed towards the observation of natural objects. Animals, plants, minerals, are collected by the schoolboy, who delights to note their shape and qualities, and rudely to compare and classify. But the thirst for natural knowledge thus early and unmistakeably manifested

is rudely quenched by unpalatable draughts of scholastic lore, administered too often by a tasteless pedagogue, who, blind to the indications of a true course of education, thus plainly pointed out by human nature, developing itself according to the laws of its own God-given constitution, prunes and trims, binds and cramps the youthful intellect into traditional and fantastic shapes; even as the gardeners of a past age tortured shrubs and trees into monstrous outlines, vainly fancying to improve their aspect, arresting the growth of the spreading boughs and the budding of the clustering foliage, mistaking an unhealthy formality for beauty. Far be it from me to disparage the educational value of the glorious literature of Greece and Rome, or to withhold due honour from the many able and learned men who give dignity to their profession as educators. To them I would appeal for the rectifying of the evils of a one-sided education. I would implore them, in the name of Aristotle, the greatest of naturalists, and most admirable of observers—how great otherwise none knows better than they do—to avail themselves of that science upon which he laid so much stress, and through it to cultivate those tracts of the mind of youth that now lie fallow and unproductive.

I speak thus strongly respecting the neglect of the sciences of observation in the ordinary practice of education in England, because it is too probable that in it lies one of the chief difficulties with which schools of applied sciences will have to contend in the outset. The rudiments of science should be taught elsewhere. The student should come prepared with a groundwork of elementary training, which there is too much reason to fear, in the present condition of schools and schoolmasters, he will have great difficulty in obtaining. The training for scientific study should be effected in preparatory schools. The teaching here should consist in the communication of scientific knowledge, and in the elucidation of the applications of it. But we do not despair. The events of this year have gone far to awaken Englishmen to the consciousness of the dignity that is inherent in those pursuits which have made their country so powerful among nations. The union of practice with science is the surest way to keep her strong

position. Through the operation of well-devised educational establishments only can that union be cemented, and future results secured.

In the scheme of education adopted by the School of Mines it will be observed that palæontology is regarded as inseparable from natural history. I have already said that the study of organic remains, conducted independently of the study of living organisms, is essentially empirical and injurious to science. The value, the interest, the scientific and practical importance of fossils, depend entirely on the knowledge of their true nature, which we gain through a comparison of them with their existing homologues and analogues. That comparison cannot be understood unless we make ourselves acquainted with the habits and organization of the living types with which fossils must be compared. There are now nearly 30,000 kinds of fossils known and described; these have been discovered in formations of all epochs. Some of them are the remains of beings that lived at immeasurable distances of time,—some of them are the skeletons of creatures that flourished along with the ancestors of species now existing. Yet all researches hitherto made have gone to show that every form of extinct life was a member of the same great series of beings with those which now inhabit our world,—that the laws of organization and the laws of life were the same in the primeval epochs of Preadamite time as now,—that the same great universal thought has uniquely pervaded the one great creative action,—that the repeated manifestations of creative power during successive ages have ever announced the one consistent idea.

It is not an uncommon fancy to suppose that naturalists are occupied entirely with the naming and describing of the kinds of animals and plants; that, provided they can enumerate in clear though technical language the characteristics or features of a being submitted to their examinations, usually in the state of a preserved specimen, and, on discovery of the species being one hitherto unnoticed, give it a name by which it may be remembered by their brother naturalists to the end of time, or thereabouts, they have attained all their aim, and fulfilled all their ambition. This notion of their duties and offices is a libel.

It takes note of only a fragment of their labours. To name and describe are but to enrol an object, with a true spelling and clear definition, in the great dictionary of science. Words in dictionaries are exhibitions of the raw materials out of which literature is made; and species arranged in zoological and botanical systems are orderly and beautiful displays of the raw materials of natural history science. Words may be wasted, and species misused. But the study of species, which is the basis of all natural history science, does not take note merely of their external or even their internal organization. It deals also with their relations to conditions in time and space. It seeks out the epoch of their first appearance, and traces them through their diffusion under favouring, or limitation and final extinction under unfavourable influences. It searches for the causes inherent to their organization, by which, of two similar yet not identical creatures, the one has the power to battle with varied and very different forces, to maintain a vitality that braves the duration and complicated arrangements of several successive epochs, and, daring alike the freezing cold of the poles and the feverish warmth of the equator, to spread its individuals over more than half the world. Whilst the other, distinguished, it may be, from its congener by some apparently slight and useless difference,—though the mark be an indelible brand by which nature has stamped that member of her flock, and that one only,—is incapable of assuming protean variations, or of enduring even a slight change in the physical conditions under which it first appeared. It enjoys a fleeting existence during a short segment of time,—dies out ere it has spread beyond a mere speck on the earth's surface, disappearing never to reappear;—perchance, if it belonged to some primeval fauna, never to become known to man, with all his research, unless some bony or shelly framework gave consistence to its otherwise perishable substance.

But so to deal with our subject, so to work at natural history, how can we proceed without the aid of geology? It is plainly impossible. From the moment we recognise a consideration of the relation to time and space of species and genus as an essential element of a right and full understanding of them, from that moment the naturalist calls in geology to his

aid. And how is geology to help him? The pure geologist,—the inquirer into the earth's physical features at the different stages of its eventful history, and into the probable nature of its internal constitution and the causes of the inequalities of the outline of its crust,—the pure geologist cannot aid him, but, in his turn, rather expects aid from the naturalist. For the geologist has been taught, by his own experience, that without an investigation of the life-manifestations at successive epochs his science is fragmentary and incomplete. But the mere describing and cataloguing, the casting of them in established zoological and botanical moulds, is as likely to mislead us as to help. Such a process has misled. Half the sins of premature speculation so often called up, like filmy ghosts, to frighten incipient geologists from the beautiful science they would follow—the charges of crudeness, hastiness, vagueness, inconsistency, and inaccuracy brought against geology—have arisen from this mode of attempting to misconduct scientific inquiry. The geologist collected fossils without sufficient notes, and without a notion of their zoological or botanical value; he transmitted them to the zoologist or botanist, who examined them without caring to know whence they came, under what conditions they were found, or who were their associates. It was like the author mentioned by the novelist, who, when called upon for an article on Chinese metaphysics, read up China on the one hand and Metaphysics on the other, and combined his heterogeneous knowledge in a wordy and well-sounding but empty disquisition. The time for such manner of work is going—has gone. The naturalist who examines fossils, if he would understand them, must study and practically acquaint himself with the principles and facts of geology. The naturalist who studies living beings, if he seek to grasp the philosophy of his science, must work among the remains of extinct creatures also. Geology must become an element of his studies. There was a time—not very long ago—there may be a few holders by it yet—when it was supposed that to be a zoologist a knowledge of comparative anatomy was superfluous; that to be a botanist no acquaintance with vegetable physiology was required. That day is gone, or expiring. The man who

would now maintain such a state of things to be science is listened to with a smile, not argued with; and so will it be with all who pretend to investigate the phenomena of distribution, and the laws which determine the limits of genera and species, without a knowledge of geology.

On the principle that there is no palæontology without natural history, that there is no natural history without geology, the relations of living to extinct forms have been borne in mind in all the arrangements of this Museum, and in all the duties of those to whom the charge of the fossil collections, made by the Geological Survey, has been assigned. Moreover, in order to carry out this view to its fullest extent, the officers of the palæontological department are required to take the field when investigations demand their presence, and to study the occurrence of organic remains in the rock, as well as in the cabinet. To do this they must necessarily make themselves familiar with the practice of geological research. They must learn to appreciate the exact bearing of physical and mineral conditions on organic remains. Such, too, is clearly the method by which a knowledge of palæontology of practical value to the mining student can be acquired.

In conducting the business of this class, I look forward to the holding of field-excursions, regarding them to be quite as essential as lectures for the instruction of the student, who to benefit by his studies must become a practical fossilist, and learn to observe carefully fossils *in situ*, and appreciate on the spot the evidence afforded by their associations. During the progress of our winter-courses this can be done effectually in the neighbourhood of London, or by means of the facilities of transport afforded by lines of railroad. I trust that before the end of this session a compact band of undaunted investigators, belted, strapped, and bag-bearing, armed with stout hammers and sharp chisels, under the veteran generalship of our director-in-chief, and officered by my mineral and geological colleagues and myself, will make the rocks shake and yield up their treasures for many a mile around the great metropolis.

In teaching the natural history of organic remains, we shall enforce the practice of the observation of them mainly through

British examples. The principles of the study shall receive a wider range of illustration. But to learn details surely, we must acquire our knowledge through that which is most precisely known. We have abundant materials in this Museum for the minute investigation of the fossils of an area in a geological sense probably the most important and typical of provinces of the earth's surface. The value of the collection does not depend merely on the number of species or beauty of specimens, though in these respects we have much to boast of; it is due to the minute information preserved in our records respecting the history of individual specimens. Every fossil collected during the operations of the geological survey has a value far beyond any accident of fineness or rarity. It has been selected especially and precisely in elucidation of a geological fact. It is a lasting and ever-consultable memorandum of a geological observation. Its locality, its associates, the abundance or scarcity of individuals of the species at the spot and in the stratum where it was found, the mineral character of the rock itself, the condition of the specimen—whether indicative of entombment when alive, or of death before becoming imbedded, or of transport before reaching the spot where, invested with sediment, it became immortalized in stone,—all these points, essential to an accurate, to a scientific knowledge of the fossil, have been carefully noted and recorded; and the specimens incorporated with the survey collections are worthy associates of them. We know who collected them, and how they were collected; and before they find a place in our cabinets their history has been traced and certified.

Such materials give confidence to the student. He feels that through them he may acquire information calculated to assure him in his after researches; he imagines for himself a safe type, a standard of comparison by which to test less perfect data. If his fate should lead him to undertake geological, mining, or exploring adventures in distant and little known lands, he will find himself far better qualified to draw conclusions respecting the age and position of fossiliferous strata than if he had come to the inquiry with a vague general knowledge such as he might gather from the inspection of a universal collection; for

an intimate acquaintance with the fossils of all regions could not be acquired by him even during many years. He has learnt not only *how* to observe, but also *what* to observe; he has gone through that wholesome training which monographic exercises in any of the divisions of natural history invariably give. Without it, zoologists, botanists, and geologists must be content to take place among mere declaimers and talkers about things, which, in the absence of practical knowledge, all possible reading and lecture-listening will fail to make them understand.

The collections of organic remains displayed in the galleries of this museum are not of interest to the student only, they have a public value: they bear testimony to the correctness of our knowledge of the geological structure of the British Islands; and, where they coincide with the operations of the geological survey, present the minutest evidence of the age and features of the strata explored, as far as fossils can afford such evidence. And as the economic value of geological observations must ever depend on their strict accuracy—on the confidence that may be placed in them by those who would invest capital or prosecute researches on account of their faith in data officially laid before the public—such tangible proofs, open to the most severe scrutiny, as collections of organic remains made on the spot by the officers of the survey, must have a practical importance, upon which too much stress cannot be laid.

In a country where riches are a title to high esteem and power, any branch of science that has no direct influence upon money-making is likely to be held in low estimation by the unenlightened. The meaning attached to the word *practical* in England is often nearly synonymous with *money-producing* or *money-saving*. Although I would be the last person to maintain that scientific establishments should be supported by the nation, or scientific researches respected, mainly on account of such recommendation, I am not one of those who would separate science from the ordinary pursuits of men, or who would desire to see philosophers withdrawing themselves from the multitude, by keeping their thoughts unmingled with the meaner aims of the crowd. When science, provided she be mindful of her honour, and make no sacrifices of her love of truth, serves as

the handmaiden of even the humblest of arts, her dignity gains in lustre, and her familiarity breeds respect. There is no department of science without some ties with the common business of life. Even palæontology may have a direct as well as an indirect influence on commercial enterprises. An example or two, out of many, may serve as an illustration.

Not long ago considerable funds were spent in a district in the west in a useless search for coal. The adventurers, ignorant of geology, had set to work in dark Silurian shales, among the oldest of stratified rocks, and far beneath our carboniferous strata. Their mineral aspect, however, resembled that of certain coal-shales with which the miners were familiar. Had they possessed even a slight acquaintance with organic remains, they would have abandoned their profitless experiment at the very commencement; for the shales in which they were working were charged with graptolites, extinct zoophytes, which do not range higher than the lowest fossiliferous group, and the presence of which indicated the true character of the strata beyond question. The fossils did not escape the notice of the miners. They collected them, and grew the more confirmed in their mistake; for, unacquainted with the differences, they mistook them for coal plants. They might have bored through the earth's centre without coming to the treasure they sought; their only chance of reaching it was by perforating quite to the antipodes.

In a second example I was myself personally concerned. Some years ago, when as yet but a student attending the geological and mineralogical lectures of Professor Jameson, I opposed by letter in a provincial journal a mistaken enterprise upon which much money was unfortunately spent. The object of it was to sink through the old red sandstone, with the hope of reaching coal, in a district where such a search was hopeless. The parties engaged were confirmed in their intentions by the advice of practical coal-miners well acquainted with the collieries of the north of England. These men argued, that since there were limestone and sandstone similar to those rocks associated with coal, and overlying it, in the districts where they had worked, therefore the strata were the same, and coal should be found. I pointed out, chiefly from the evidence of the fossils contained

in the limestone overlying the sandstone, that the rocks on which they proposed to operate were only like to, but not identical with, those to which they were compared. I told them,—the warning was proffered in vain,—that they were throwing away their money. One of the shareholders, an intelligent man, and a reader of elementary works on geology, replied to my objections by attempting to meet them on scientific grounds. In some old-fashioned books it used to be asserted, that shells of the genus *cardium*,—in plainer language, cockle-shells,—when found fossil, are characteristic of tertiary strata. "Now," wrote my opponent, "cockles abound in the limestone in question, therefore it is tertiary, and the carboniferous strata must lie beneath." He had mistaken certain forms of *terebratula*, shells of a very different order, for cockles; a very unfortunate mistake, for the error was persisted in, and much good gold turned into irredeemable dust.

I have cited these instances because they not only show how serious an error, leading to considerable pecuniary losses, may be committed in consequence of ignorance of science, but also are examples of the danger of inaccurate or fancied knowledge. In both these cases the fossils were noticed, but, through ignorance of these distinctions, altogether mistaken.

There is much popular palæontology abroad, as likely to mislead as to guide. The practical value of this section of natural history depends upon its certainties, and not upon its uncertainties. In the former class may be placed the determination which fossils afford of the origin of rocks, whether they be marine or estuary or fresh-water deposits; of the relative ages of sedimentary strata; of the indications they give of the climate of different epochs; of the information they contribute respecting the ancient physical geography of our globe; of the testimony they bear to the unity, harmony, and benevolence of the Divine scheme of creation,—the same during incalculably distant centuries of primæval time as now.

Under the head of uncertainties may be ranked theories of transmutation of species; of progression towards perfection; of universal diffusion of species at ancient epochs; of the retrograde development of animal and vegetable forms in time; of original perfection and subsequent degeneration; of original

generalization of specific types, and subsequent specification; of differences in the physiological habits of creatures anciently and now. All these notions are hypothetically or theoretically advocated, more or less, by men of science at the present day. All of them, it seems to me, are at best inductions from insufficient data. They may or may not be true, but at present, as we may see by a glance at the comparative extent of our knowledge of existing and extinct forms, we are not in a condition to come to a decision on the important questions they involve.

The collections of fossils displayed in the cabinets of this museum are highly illustrative of the great truths of geology, and are arranged so as to convey instruction on the fundamental principles of the science. The fossils of each formation,—in stricter language, the creatures of each epoch in the Preadamic history of the earth's formation,—are grouped together, and each group is displayed in strict geological sequence,—in order of superposition of strata. Whoever studies these collections carefully may gain a clear conception of the nature of the proofs afforded by natural history of the vast duration of the earth, and the series of epochs, each characterized by a distinct creation of organized beings, that have preceded the present condition of animated nature.

Although in the commencement of our educational efforts we can scarcely hope to embrace all the subjects that spring out of the arrangements of this Institution, it behoves us to look forward to the utilization in other directions than that of geological science even of its natural history resources. There is a great blank yet unfilled in the teaching of the numerous applications which may be made of natural history to the arts. Charming as are the exquisite examples of ceramic, vitreous, and metallic manufactures collected in our Museum, we cannot but feel that the workman, however fine his natural or acquired taste may be, is unaware of the vast variety of beautiful shapes and designs that lie unused in the treasury of nature. The aiding of the manufacturer in the perfecting of his works is one of the aims we profess. The chemist can teach him how to improve his materials, or furnish him with new substances and new

pigments to use in his art; the metallurgist can show him those metallic compounds that can give the finest effect to his castings; the mineralogist and geologist can open out fresh stores of ore and earth suitable for his operations. Cannot the naturalist also come forth with friendly aid, and render some good service?

The relations of natural history with the arts are of two kinds, either illustrative or suggestive. To the first belongs the inquiry into the nature and sources of the numerous products derived from the animal and vegetable kingdoms, and applied, or capable of being applied, as direct materials for arts and manufactures. A more perfect acquaintance with old and a discovery or indication of new materials adapted for the exercise of human skill and workmanship may thus be attained. But the naturalist may render higher and at the same time as practical services to the craftsman, by furnishing out of the endless store of beautiful objects that are rendered familiar to him by his scientific pursuits sources of new and exquisite design,—fancies originating in the teeming brain of nature,—God-born thoughts, that become manifest in living shapes,—all consistent,—never jarring,—in every part admirably adapted to each destined purpose. Now the laws of these adaptations and harmonies, the proportions by which the beauty of living things is maintained, the ideas by which similar forms have been grouped in nature, and, though like exceedingly, yet wondrously dissimilar,—these are among the earnest studies of every philosophical naturalist. Surely out of such studies lessons applicable to art may be derived! What is ornamental art but the isolation and embodiment in works of human skill of the beauty that is diffused through all the works of God? And that beauty lies, not merely in the bulk of objects, nor on their surface, but is as manifest in every part and atom composing them as in the combined whole. It is in itself composite; the combination, not of lesser, but of minuter beauties. To imitate,—to approach,—we must attempt a like arrangement, in order to obtain the same exquisite result. And how, except through earnest and scientific study, can we attain the knowledge that shall enable us to discover the pathway leading towards perfection?

On the Importance of Cultivating Habits of Observation. (*The Introductory Lecture to the Course on Mechanical Science. Session* 1851–1852.)

By ROBERT HUNT, Keeper of Mining Records.

IN studying the phenomena of human progress we discover much that is of the highest interest to the philosopher, as illustrating the manner in which the powers of mind have been turned to the investigation of the works of creation, and displaying, at the same time, the beautiful re-action of each discovered truth in the improvement of man's social state.

The past must ever be the teacher of the present, and a bright or clouded future is entirely dependent upon our appreciation of its teachings.

Man, gifted with exalted powers, is the inhabitant of a most wonderfully constituted world, and according to the industry with which he exerts his reason he becomes the possessor of its wealth.

The animal necessities of the race are the primary exciters of the reasoning powers, and we find uncultivated man exerting his intelligence only to snare and destroy beasts, to furnish him flesh for food, or skins to shelter him from atmospheric changes. From this state he advances to a pastoral one, and studies to lessen his toils by domesticating animals, and thus escape from the perils and uncertainty of the chase. In the repose of a shepherd's life habits of contemplation appear to have had their earliest birth, and the phenomena of nature to have interested the human mind. Attention once awakened to the ever-changing, still recurring operations of organic life,—to the mysteries of alternating light and darkness,—the gradual and regular passage of the seasons,—the beauty of the stellar vault,

and the meteoric displays which are for ever occurring in the earth's atmosphere,—an imperfect science slowly crept into existence, the full development of which was long retarded by the misty superstition with which man invested all things that he could not comprehend.

Without attempting to analyze the psychological progress of man in his study of the exacter sciences, which will, however, be found to be dependent upon his habit of methodizing ideas, we may, by confining our attention to the simple discovery of natural truths, see that all advancement has been the result of *experience.*

Facts frequently returning have at length solicited attention, and thus is cultivated habits of *observation.* By close attention new features are discovered in the phenomena; results which had long escaped casual and heedless glances are developed, and the mind is thus led up to the inquiry after the exciting cause. True science now begins, and the evidences of *experiment* are sought. A philosophical method is eventually developed, and its operations are displayed in the careful classification of observed phenomena, in the consideration of which the human mind necessarily demands the assistance of *theory;* and as this is constructed in accordance with true observations, or in obedience to the exuberant thoughts of an imaginative mind, is the discovery of truth accelerated or retarded.

To the record of careful observation we owe the first or initiative idea of every truth. The earliest duty, therefore, of every teacher is to train and educate the mind in habits of close and exact observation.

Man cannot create, but he is endowed with powers by which he may examine everything which is created, and by combination produce results which are to the uninitiated but little short of a creation, when applied to the amelioration of some of the necessities of mankind. Human intelligence has bound the physical forces to do man service, and all the great applications of science may be referred to in proof of the position that human progress is directly dependent upon careful observation, and the habit of recording, in a systematic manner, the facts which have been thus developed to the mind.

The history of every science affords examples of this; the devious and uncertain wanderings of the astrologer, the alchemist, and the cosmogonist exhibit the severe struggles of truth through the mazes of imagination; while the advancement of astronomy, of chemistry, and geology may be appealed to as expressive of the advantages of working diligently with a system of observation for our guide, and waiting patiently for the development of the truth.

It has been said, and said too by a great authority, that in experimental science we owe much to accident. Depend upon it, however, as a general rule, there are no accidents in science. It is true that often in the progress of an investigation an unexpected circumstance gives rise to a new train of inquiries; new ideas are the result, and discoveries the consequence: if that which may be regarded as an accident does not generate a clear idea, and generalize a correct system of inductive search, it remains a valueless fact.

Thales of Miletus observed, that amber being rubbed attracted light bodies. Here was a fact, probably of accidental discovery, which failed to produce a definite idea; and remember, nearly 2,000 years passed away before man detected the truth that the *electron* of the Greek philosopher was a source of the all-diffusive agency, electricity. Galvani noted the convulsive movements of frogs, when the moist surface of their bodies was in contact with two metals of unequal affinity for oxygen; this generated a correct idea in the mind of Volta. Step by step induction has followed in this path, and we have, within a period of sixty years, the discovery applied to metallurgical processes of great utility, and to the valuable one of firing simultaneously any number of holes in the operation of blasting rocks, by which the sinking of shafts and the driving of levels in our mines are carried on with great rapidity and much economy. Following on the same tract Œrsted proved that a copper wire under the influence of an electric current became a temporary magnet. It was soon shown that an iron bar placed within an helix of such wire acquired most powerful magnetic properties; and within twenty years this knowledge has been applied to measure the tread of time, and to be the winged messenger of

human thought, surpassing beyond all limits the speed of the "tricksy Ariel," and leaving the hurrying tempest like a laggard in its path. These facts were adduced by my colleague, Dr. Playfair, in support of his arguments when discoursing of the value of abstract science; but as it will be my duty to show you in the progress of my course the experimental evidence to which reference has been made, I have not hesitated about repeating the striking illustration which these physical forces lend to the position I maintain. I cannot allow the present opportunity to pass without drawing attention to the evidence afforded by the attempts which have been made to apply the electrical element as an illuminating and mechanical power, of the danger of attempting to do so before we have acquired an accurate knowledge of all the phenomena which are involved in the conditions of the application. In the arc of light produced between the poles of a powerful voltaic battery we obtain the most vivid illumination which can be produced by artificial means. Ingenious mechanical contrivances have been devised to render the distance uniform between the charcoal points, which form the polar terminations of the wires, and thus to give steadiness to the electrical light, but since there is a constant transfer of the solid element from one pole to the other, the required steadiness has not yet been obtained. The question of the economy of this application, even if successful, may be conveniently embraced in connexion with the consideration of the application of electro-magnetism as a motive power. It has been stated, and is indeed now well known, that we can obtain an enormous attracting and repelling force by the agency of electro-magnets. In some cases magnets have been placed upon the periphery of a wheel, while others have been fixed upon a firm circle surrounding it. By mechanical contrivances the polar disposition of the magnets has been rapidly changed. The consequence of this is the exercise of an attracting and repelling power, by which the wheel is driven swiftly round. Another form of construction, offering some advantages, is a cylinder, around which clothed copper wire has been coiled, thus forming a hollow magnet, into which another solid magnet representing a piston is drawn, and from which, by changing the

poles, it is afterwards repelled. By this means a long stroke is obtained, and by a crank any kind of machinery set in motion.

The first difficulty which has to be encountered here is the very great rapidity with which the power diminishes through space. An electro-magnet which will sustain 220 pounds when the armature is in contact with its poles, exerts an attractive force of 40½ pounds when the armature is at a distance of one fiftieth of an inch only. Now you will perceive that under any of the arrangements which have been adopted the moving and the fixed magnets could not be brought nearer together than the fiftieth of an inch; hence there is an immediate loss of four fifths of the power we have produced.

The second difficulty to which I had the satisfaction of first directing attention in this country, although I have since been informed that it had been detected by Jacobi, is, that the moment the magnets begin to move there is a temporary loss of power, or, perhaps, it would be more correct to say, there is a development of an opposing force, by which the mechanical power is again considerably diminished; and the greater the speed with which the magnets move, the more rapidly does this decline. The report made by order of the American government on Professor Page's electro-magnetic engine directs attention to this fact, which the reporting engineers were not able to explain. Mr. Hjorth, the most recent inventor and patentee of electro-magnetic engines, after the publication of my paper, observed the influence of these induced currents, and with a view to economy endeavoured to employ them in effecting the precipitation of the zinc, from the sulphate of zinc formed in the voltaic battery employed, but without success. Such are the difficulties which at present stand in the way of applying electricity as a motive power. It may be said, that these resolve themselves into questions of economy. Granted. The whole of this question I have investigated with the closest care, and the result is, that a grain of coal consumed in the boiler of a Cornish steam engine will lift 143 pounds one foot high, whereas one grain of zinc consumed in the voltaic battery will lift but 80 pounds through

the same space. Now the cost of zinc is 216*d.* per cwt., while the cost of coal is but 9*d.* per cwt. It will be my duty to show and explain early in the present course of lectures that the development of power, of whatever kind, is always accompanied by a change in the form of matter somewhere. To obtain a given amount of exertion from a horse we learn that it is necessary to give him a larger quantity of food than when he is at rest. If we desire to impel a locomotive engine at a high velocity we are compelled to supply an increased quantity of fuel, that steam may be generated with greater rapidity. We know of no development of force, whether heat, light, electricity, or muscular power, without such a change in the form of matter as amounts, to us, to its destruction. Muscle is consumed in every exertion of animal strength. Carbon and hydrogen in like manner are burnt in producing our artificial lights, either as gas, oil, wax, or tallow, and also in the production of heat, whether in our domestic fires, the furnaces of our manufactories, or the boilers of our steam engines. We evoke electricity by several methods of disturbance, but we have only now to consider that means of development which depends upon chemical action. Although we employ magnetic force, this is dependent on the power which is produced in the voltaic battery, and the zinc or any other element which may be employed is converted into some new form. Zinc, for example, is changed by the action of sulphuric acid in the battery into sulphate of zinc; and the advocates of the application of electricity as an illuminating or moving agent on the ground of economy state, and truly state, that the salt may be reduced and the metal revived. From my investigations of the whole question I feel assured that I state a truth in saying the coal employed in reproducing the metal would afford as much light, heat, or mechanical power as that obtained by the destruction of the metal in the first instance in the battery.

Let me not be misunderstood. In the present state of our knowledge I deem it hazardous to attempt to apply electro-magnetism instead of steam. Notwithstanding the rapid discoveries made in every branch of electrical research, and the great power which we can command in our voltaic arrangements,

it must not be forgotten that the quantity of electricity obtained is exceedingly small in comparison with the quantity which exists in the elements constituting the voltaic battery. Dr. Faraday, whose experimental researches in electricity must be regarded as the finest example of inductive investigation to be found in the annals of British science, and the most perfect exemplification of the philosophy of Bacon to which the student in physics can be referred, has proved that a single drop of water holds imprisoned in its liquid chains a quantity of electricity which equals that contained in an ordinary thunder-cloud. In every form of the voltaic battery a very large quantity of electricity is lost in passing from the liquid to the solid element, and the contrary; so that in overcoming the resistance nearly three fourths of the power is consumed.

Allow me to give another example of the value of close observation in connexion with magnetism. Dr. Faraday was the discoverer of the fact, that when a hollow helix of copper wire containing a core of soft iron was moved in front of or near the poles of a permanent steel magnet, electricity was evolved, and all the results of voltaism readily produced. Hence the formation of magneto-electrical machines; and in the great electro-plating establishments of Birmingham we may see the process carried on by the current thus generated by the revolution of coils of copper wire placed on an iron armature near the poles of an ordinary steel magnet.

To the true philosopher everything, howsoever insignificant to ordinary minds, is felt to deserve attention, and the minutest phenomena claim the most accurate study. A body falls to the ground,—a drop of water hanging from a rod, or resting on a leaf, assumes a spherical form. Nature is asked, Why is this? and the answer is the discovery of the law of gravitation, by which power each planet is retained in its orbitual path around the sun, and the entire solar system, held as completely in union as the particles of the water-drop, moved through space under the influence of a gravitating force resident in some far distant and probably unseen star. Reflection on the discovery of the planet Neptune must lead to the conviction of the truth of the Newtonian law of gravitation.

Up to the year 1804 the planet Uranus moved in its orbit without any appearance of disturbing influences; but at that period an accelerated motion became evident, and this continued until 1822, when the planet's rate of progress was retarded, and this has continued to the present time. It was felt that according to the law of planetary disturbance, the gravitating action of Jupiter and Saturn not being sufficient to explain the perturbations, it was probable that a mass of matter exterior to our known system was the exciting cause. In this state of the question the following problem became the subject of investigation to Mr. Adams, in England, and M. Leverrier, in France, unknown to one another:—"*Given the disturbances to find the orbit, and place in that orbit, of the disturbing planet.*" These geometers arrived at conclusions differing from each other only 3° 19′; and M. Leverrier having announced to Dr. Galle, of the Royal Observatory of Berlin, the position in which a new planet,—the disturbing cause,—should be found according to his calculation; on the very night of the day on which the letter was received the astronomer of Berlin discovered the planet Neptune in a point of space differing only 47′ from the mean of the two calculations. The planet Neptune, like the old planet Saturn, is surrounded by a ring. Allow me for one moment to direct attention to some experiments by Plateau on the condition of bodies relieved from the influence of gravitation, which appear to show that the remarkable phenomena of these two planets, with their luminous rings, are due to the influence of motion exerted under peculiar conditions. If oil is dropped upon water it swims; if upon alcohol it sinks; but if we make a careful combination of water and alcohol we obtain a fluid of the same specific gravity as the oil, and the globule of oil will swim in the very centre of the fluid, a perfect sphere. If into a properly arranged glass box we pass a fine wire through the sphere of oil, and by means of a handle cause it to revolve slowly, the sphere becomes an oblate spheroid; by increasing the motion we flatten it still more, until at a certain rate of revolution it becomes a disc, when a ring of oil is thrown off from the central globule, and although separated by intervening water, it revolves at precisely

the same rate. It is not a little interesting thus to find mechanical science affording us the means of explaining the grander phenomena of creation.

The force of gravitation has its practical application in the ordinary forms of water-wheels, the falling water producing a continuous circular motion. In the hydraulic pressure engine, of which we have a beautiful model in the museum, the gravitating power of the water is the moving force. In the windmill we see the operation of the same power; and in the earlier engines, as those of Newcomen, Savery, and Watt's first single acting engine, the return of a heavy mass under the influence of gravitation and the atmospheric pressure—a result of the same principle—was the leading element of power. The works of Archimedes and of Hiero of Alexandria show us that the ancients were well acquainted with the operations of this agent, although they had not arrived at any correct idea of its law of action. It is to a neglect of the laws of gravitating force, and of the principle of action and re-action which prevails in every mode of motion, that the idle problem of producing perpetual motion has so frequently led ingenious minds aside from the path of usefulness which they would otherwise in all probability have pursued.

To continue our examination of the importance of minute observation, every step of progress from the employment of steam to produce a continuous motion, by Ptolomy Philadelphus, 130 years B.C., to the discovery by Watt of the expansive force of steam in 1782, might be quoted in exemplification.

We find Branca and Kircher employing the force of a jet of steam to drive the vanes of a wheel.

Baptista Porta observed the pressure exerted by confined steam, and he used it to raise water.

The discovery of the pressure of the air, and the investigations of Torricelli, Pascal, Guericke, and Boyle, led to the construction of engines by Worcester and Papin, in which the elastic force of steam and atmospheric pressure were combined in action.

Thomas Savery, carefully studying all that had been done previously, appears to have first conceived the correct *idea* of the force, and to have applied it with much greater success than any

of his predecessors. In 1698 he got a patent for his discovery, calling it an invention "*for raising water, and occasioning motion to all sorts of millwork, by the impellent force of fire.*"

Newcomen, an ironmonger at Dartmouth, associated himself with Cawley, a plumber of the same place, and they together carefully investigated the phenomena of atmospheric pressure, and the formation of a vacuum by the agency of steam; and Newcomen certainly transformed an imperfect, and for many purposes a useless machine, into a really efficient steam engine, which could be applied profitably and safely to the most important uses. Newcomen should share a pedestal by the side of Watt; the ingenious contrivances of the obscure ironmonger of Dartmouth, the result of minute observation, have had much to do with the advance of civilization.

Of the inventions of Watt it is scarcely necessary to speak; the fertility of his genius is known to all; and the history of his progress informs us that every advance made by James Watt was a comment on the text I have chosen,—the value of observation. Of the importance of the inventions of James Watt well may Arago, in his Éloge, speak as follows:

"We have long been in the habit of talking of the age of Augustus and of the age of Louis XIV. Eminent individuals amongst us have likewise held that we might with propriety speak of the age of Voltaire, Rousseau, and Montesquieu. I do not hesitate to declare my conviction, that when the immense services already rendered by the steam-engine shall be added to all the marvels it holds out to promise, a grateful population will then familiarly talk of the ages of Papin and of Watt."

Heat, as a force or principle, most intimately connects itself with the steam engine, and we are hence led on to a consideration of some of the phenomena which are associated with calorific action. Water at the level of the sea boils at 212° of Fahrenheit when under ordinary conditions. The minute observations of a Belgian engineer have led to the discovery that, when water freed from air is exposed to heat, ebullition does not commence until it arrives at a much higher temperature, and that then it occurs with almost explosive violence. He has also proved that if water in this state is brought to the temperature of 250° or

260°, and then a single drop of water containing air be allowed to fall into it, that the whole volume becomes agitated in a terrific manner, that indeed an explosion occurs.

Who amongst the thousands inhabiting those regions of the earth, where water is rendered solid by the reduction of the winter temperature, but has noticed the air bubbles enclosed in the transparent ice? None of these thousands discovered a great fact in this until Professor Henry was led to examine it. The result of that investigation has been the discovery of the remarkable truth, that water in the process of congelation actually squeezes out everything it may hold in solution, and becomes far more pure than it can be rendered by any other means. If water holding air, colouring matter, or saline bodies in solution is, while being frozen, kept in a state of slight agitation, the air, the colour, and the salt are all rejected alike, and a tasteless, colourless, transparent ice remains. It is curious to see how near a great truth men often are, and how long they allow it to escape them. It has been the constant practice of the Russian nobles to place their wines in ice until they were frozen, for the purpose of obtaining the small quantity of ardent spirit left in the centre of the mass. The water of the wine in freezing liberated the alcohol and flavouring matter, and a pungent cordial was thus obtained.

Ice thus free of air, if melted out of contact with the atmosphere, may be heated to nearly 300°, when, instead of boiling, it explodes. How nicely balanced are the conditions of all things in nature! We now learn that if water was not the all absorbing body which it is, it would be as dangerous to expose it to heat as gunpowder or any other explosive compound. This interesting discovery promises to throw some light upon many of the steam-boiler explosions, which will form a subject of inquiry in the present course. As another illustration of the manner in which we have, from the defective character of our education, allowed phenomena continually presenting themselves to us to escape attention, look to the investigations of Boutigny. That drops of water thrown upon hot iron arrange themselves into spheroids, and move about with a peculiar internal motion, is nothing new. Yet who amongst us suspected that these

dancing drops were telling a story to man which will in all probability completely change our ideas of the properties of heat?

If two similar metal vessels are taken, and one is filled with water, which is allowed by the action of an ordinary fire to boil in the common way, we know what then takes place; but if we allow the other to become red-hot before we fill it with water, and when full maintain it at a red heat, the water will never boil. The former vessel will soon be emptied by the evaporation of the water in ebullition, but that water in the red-hot vessel forming itself into a spheroid, rolls about, it never gains a higher temperature than 150° or 160°, and it evaporates but slowly. Again, at the temperature of red-hot iron chemical affinity is suspended, and if we project into an iron crucible thus heated, many bodies having the most powerful affinity for each other, they will not enter into combination, but remain separate spheroids rolling around each other. The investigations of Boutigny in this path have proved that the repulsive power of heat at elevated temperatures is so great that the naked hand may be plunged into melted iron without injury, and that the wondrous feats of the Magians and the tricks of the conjuror can be performed with impunity by the philosopher. No less than three patents have been taken out in England for generating steam with great rapidity. In one water was dropped into red-hot tubes, in another it was thrown upon red-hot plates of iron, and in another heated mercury was employed. It was thought that the water would be *flashed* into steam, and an immense power obtained, but in every instance failure followed the experiment. The investigations of Boutigny show the cause of failure, and prove the importance of experiment at every step we make in our endeavours to employ the great powers of Nature to do us service. Recently in France attempts have been made to employ water in this spheroidal state to work a marine engine. It being thought that as the vapour which escapes from the spheroidal water is of the high temperature of the surface upon which it is formed, that it would, from its extreme tension, furnish an enormous amount of power. The experiment has not been, even in this case, successful hitherto.

Mr. Woolfe, to whom the Cornish steam engine is indebted for many improvements, once tried an experiment in the presence of Mr. Davies Gilbert and some other gentlemen of a very remarkable kind, the result of which bears in a striking manner on the investigations alluded to. A measured quantity of water was placed in a boiler, all the safety valves were most carefully closed, and every chance of the escape of steam prevented. The fire was now got up, and for some time the steam gauge indicated a regularly increasing pressure. At length, to the surprise of all, the pressure was seen slowly, but gradually, to diminish, and although the boiler plates became so hot as to char the wood which surrounded them, this remarkable phenomenon continued, and when the boiler had cooled it was found that no water had escaped. These investigators conceived no correct idea from this hazardous experiment, but it was the Caignard de la Tour experiment of enclosing elastic fluids in hermetically sealed tubes, repeated on a large scale, and it showed, as all the experiments of Boutigny show, that notwithstanding our boasted knowledge we are yet ignorant of the laws which govern the operations of heat when its excitation is elevated. The decomposition of water by heat, as discovered by Mr. Grove, belongs to this class of phenomena, and Dr. Robinson, of Armagh, in considering the experiment, speculates on the probability, that at a certain point *heat* may be changed into a *chemical force*, similar to those radiations from the sun which effect the changes now familiar to all of you in the photographic processes, to which the term *Actinism* has been generally applied.

Although it will be my constant endeavour to explain with all care the useful applications of science; to show how thoroughly associated science and practice should be, I shall never fail to direct attention to those experimental evidences which enable us to interpret the great phenomena of nature. As a cultivator of physical science I feel that half of the advantages to be derived from the study would be sacrificed, if the satisfactory manner in which advancing science opens out to the contemplative observer new harmonies in creation, and tends to exalt the mind to higher and holier aspirations was not shown.

In connexion with heat, observation has proved to us numerous important points relative to its distribution over the earth's surface. The Isothermal bands connect themselves with the phenomena of animal and vegetable distribution; and still more strikingly, we are beginning to discover an intimate connexion between those regions of mean equal annual temperature and the great phenomena of terrestrial magnetism. The conditions of the ocean currents,—as, for instance, the Gulf stream setting northward from the Gulf of Mexico, and ameliorating the conditions of our own winters,—are worthy of careful study. The waters of the sea upon our western shores are always several degrees warmer than the adjoining land, and during last winter the ocean temperature was found to be two degrees higher than usual. May not the mildness of that season have been due to the influence of that current of water, warmed in inter-tropical climes, flowing northward, and yielding up its store of heat to the shores of these islands?

This ameliorating influence is strikingly shown in Norway. On the southern coasts of that country, which are sheltered from the Gulf stream by our own islands, the cereals will not grow; but further northwards, where the great current setting to the north of Scotland reaches the Norwegian shore, the climate is rendered sufficiently mild for the growth of grain crops.

Again, the trade winds and the monsoons are entirely dependent upon the operations of heat; and careful observation has shown that the tornadoes of the West Indies and the cyclones of the Indian Seas are entirely due to the action of currents generated by the intensely heated surface of the earth. Notwithstanding the valuable researches of Sir William Reid, and others, proving the rotatory character of these storms, I am not satisfied that we have yet had a correct theory of the physical causes in action to produce them.

These storms are revolving masses of air, with currents rushing from the circumference to the centre, and blowing up through that centre; these systems of air in violent motion being sometimes many hundreds of miles in diameter.

The simplest explanation appears to be, that a comparatively small column of air is formed by contact with the heated earth,

which ascends with much rapidity. Take the example of a jet of steam, which in rushing from a boiler under high pressure draws all surrounding light bodies into it, and urges them upwards; the same phenomenon is shown in rapidly flowing water. The jet generates rapid currents on every side; these increase the diameter of the moving mass, and it progresses, continually increasing in size; all the currents rushing in towards a moving centre, and upwards through that centre as through an inverted tunnel. The barometer is the truthful indicator of a diminishing pressure as the centre of the storm approaches the place of observation; and thus the mariner is, by careful attention to this instrument, enabled to determine the exact position in which his ship may be placed relative to that centre.

The importance of a knowledge of the Law of Storms, and consequently of the means of escaping from the influence of these hurricanes, and of indeed employing them to aid the ship's progress, cannot be overrated. The development of the Law furnishes a fine instance of the value of observation.

Examples of a similar kind might be quoted in connexion with electrical science. Careful observation has dispelled the erroneous idea of metals being lightning attractors; and we must be charged with negligence if we allow any elevated building to be without its pointed rod, by which the thunder cloud may be quietly discharged. The lightning is no more attracted by a pointed metal rod than is the rain falling upon a housetop attracted by the pipes placed so as to allow the water to flow to a lower level; the rods furnish the channel through which the electricity freely flows; and tower or ship may be surely protected if provided with bands or rods of copper sufficiently large to carry off the accumulated electricity, and to restore the equilibrium of forces.

The electricity of mineral veins has been a subject of much interest; it having been supposed that the currents detected were indications of the operations of this agency in producing the metalliferous deposit. From my own investigations in the principal mines in Cornwall I am disposed to consider these electrical currents as due to the chemical decomposition going on within the lode itself. It must, however, be admitted that

the peculiar disposition of dissimilar ores within the same mineral lode, the alteration in the character of the lode or vein after a dislocation has taken place, the generally uniform direction of lodes, and many other phenomena which it will fall to the province of my colleague, Mr. Warington Smyth, to describe, appear to show the probability of such a power as electricity, in some of its modifications, being the exciting agent. This is one of those extensive subjects which yet remains open for the investigation of an intelligent and industrious observer.

'In a course of lectures which is to embrace a consideration of the physical forces the phenomena of the solar radiations cannot be omitted. The practice of photography belongs to these, and furnishes another choice example of my text,—the value of observation. The alchemists observed that a certain salt of silver was blackened by the solar rays; but as this did not generate in their minds any correct idea, the truth thus discovered lay dormant for ages. Eventually the Swedish chemist Scheele discovered that a certain class of the solar rays only possessed the property of darkening this salt of silver. Following in his tract, M. Berard at length, by an important series of researches, determined the extent of chemical action at either end of the solar spectrum, and speculated on the probability of light and the radiations producing chemical change being dissimilar agencies. These investigations led up to the first photographic experiments which were made by Wedgwood of Etruria, which, although not successful, as far as the fixing of the pictures obtained, were interesting examples of the production of images by the pencil of the sunbeam. Niepce and Daguerre, and more recently Fox Talbot and Herschel, investigated the phenomena of chemical change as produced by solar radiations; and the perfection of all the processes of photography is the reward of the careful observation of the change of colour produced in a white compound of silver and chlorine. Omitting, however, all mention of the useful applications of photography as a means of making philosophical instruments self-registering, allow me to state that a careful investigation of the thermic influences of the solar spectrum, associated with a physical analysis of various trans-

parent media, led me to the discovery of a glass, but slightly coloured green, which possesses the property of separating and keeping back a class of solar rays remarkable for their scorching power, and which, without obstructing any of the necessary radiations, thus protects the tropical plants in the great conservatory of the Royal Botanic Gardens of Kew from the injurious influences of scorching sunshine.

The solar spectrum exhibits several distinct phenomena. Light, heat, and chemical action are evident; and these give rise to electrical disturbance. Beyond these a class of radiations have been detected, which have the combined action of the heating and chemical rays, but which are in many respects dissimilar to either. These rays increase in quantity relatively to the other principle as the seasons advance; they being most abundant in the autumn; when, in all probability, they perform an important part in the ripening of fruit. These are the rays which, it has been found, operated to produce a kind of scorching on the leaves of those plants which grow in houses glazed with a white glass. To obviate this, was the problem submitted to my care; and the suns of two summers and autumns have shown that my experiments did not deceive me. No case of scorching has taken place upon any of the plants in the beautiful palm-house in Kew Gardens. It is important to state that an entire absence of manganese in the manufacture of the glass is demanded, and that the addition of a small quantity of oxide of copper is required.

Did time permit me I might proceed to show you, that even those discoveries which have most the character of accidents, as that of iodine by a soap-boiler, and of the beautiful blue pigment, ultramarine, in the manufacture of soda, ceased to be so by generating ideas which led to their scientific investigation. Iodine and artificial ultramarine form large branches of industry, both having resulted from careful observation; and in the latter instance we have produced a pigment which formerly cost eight guineas an ounce, but now to be obtained for less than eight shillings a pound. Learn to observe closely and accurately, and numerous other similar results must be the reward.

Mechanical science embracing a consideration of all the means of employing the powers of Nature to aid man in subduing Nature, is necessarily a wide field. It will be my object in the first course of lectures on applied Physics to deal simply with the rudiments of our science, advancing gradually to the higher phenomena. To show the intimate connexion of science and practice, the one aiding and advancing the other, will be my constant care, and in expounding the discoveries in Natural Science I hope to lead the mind to the study of those ennobling truths which constitute a

> " Divine Philosophy!
> Not harsh and crabbed as dull fools suppose,
> But musical as is Apollo's lute,
> And a perpetual feast of nectar'd sweets,
> Where no crude surfeit reigns."

On the Science of Geology and its Applications. (Being the Introductory. Lecture to the Course of Geology. Session 1851–1852.)

By ANDREW C. RAMSAY, F.R.S.

CENTURIES have passed since some of the more obvious of geological phenomena first began to attract the attention of a few of the early cultivators of natural science; but it was not till after the revival of literature in Europe, that some of the subjects contained in the wide field of theoretical geology began to be actively canvassed by many bold and inquiring spirits. For nearly three hundred years numerous authors touched upon the subject in their writings, or devoted elaborate treatises to its illustration: the works of such men as Fracastoro, Leonardo da Vinci, Steno, Scilla, Colonna, Moro, and Generelli, in Italy; of Palissy and Marsilli, in France; of Raspe and Fuchsel, in Germany; of Woodward, Ray, Hook, Strachey, and Mitchel, will ever be interesting to the student who delights to trace the early development of the science: and though its progress was slow, (down almost to the time of some of the living fathers of a more advanced geology,) yet great was the benefit it derived from the interest excited by the continuance of speculation, whether true or false. Few believed, yet little by little some scattered truths were elicited, which by degrees prepared men to throw aside the prejudices that restrained them from grappling with the subject in the only manner that could ensure its full development. For geology was not so fortunate as chemistry, when princes vied with each other in the encouragement of alchemical discovery. There was nothing heretical in the transmutation of baser metals

into gold. Geology, on the contrary, was long esteemed a pestilent heresy, and though its cultivators escaped the prison, yet, even to our own day, a few angry men are not found wanting, who, steeped in ignorance or a mistaken zeal, still re-echo the time-worn cry. For all purposes of the continuance of error, that time has however passed away, and educated people cease to regard as dangerous, and the disturbers of truth, those who follow to the utmost the legitimate investigations in physics and natural history opened out by the comprehensive labours of the geologist.

No science, save chemistry, has in the same short time made such rapid advances as geology. While the former began to assume its true position under Black, Cavendish, Priestly, and Lavoisier, geology received a new stimulus in the grand generalizations of Werner, Hutton, Cuvier, and Smith; and of late years so rapid and wide-spreading has been its progress, that no single mind can grapple with all the details of its numerous branches.

Of these the chief are :—

1st. Physical geology.
2nd. Palæontology.

The first deals with the nature and modes of formation of rocks, such as the laws that regulate and have regulated the origin and manner of distribution of strata, the nature of subterranean heat, its present and past effects beneath the surface of the globe, and the exterior igneous phenomena dependent on its operation; the disintegration, slow movements, or more violent disturbances traceable to these, or other causes, of which the present configuration of land and water is the sum; and the means consequently yielded by these apparent breaks in the continuity of order, of demonstrating the law of the superposition of strata, and of succession in geological time.

Here it is that palæontology, or the history of the old life of the world, comes to our aid. The time is not very far removed when, under such names as glossopetræ, cockles, and petrifactions, those wonderful organisms that abound in rocks, were confounded by the curious with crystalline and other mineral

substances;* and though Hook had hinted at, and Fuchsel almost pointed the way, it was not till William Smith clearly enunciated the doctrine of the characterization of masses of superimposed strata by distinct assemblages of fossils, that their study acquired that scientific value by means of which the geologist is enabled to identify groups of strata, though broad oceans roll between. Miscellaneous heaps of organic remains, collected without reference to their geological locality, have no longer any beyond an accidental value to the scientific geologist, nor can an earnest worker in the broader fields of the science now afford to consider the labours of the palæontologist as extraneous to his object. They are indissolubly linked together; the evidence afforded by each is indispensable to the other; and though a man may be a geologist without being thoroughly versed in palæontology, yet if he wish to qualify himself for work, whether economic or theoretical, that may extend beyond the petty details of mere local operations, he will find it needful to be acquainted at least with the principles of palæontology, and to familiarize himself with the general groupings of the organic forms preserved in the larger subdivisions of the strata that constitute by far the greater proportion of the rocks composing the crust of the earth.

So also in mineralogy, a science that by many has been looked on as a mere branch of geology. Viewed in such a light, geology being the history of the earth, animate and inanimate, we might well ask, how many are the material sciences that do not, directly or indirectly, spring therefrom? No man considers comparative anatomy a mere branch of geology. Nevertheless it is an essential ally. So is it with mineralogy, the modern progress of which rather throws it into the domain of physics and chemistry; for, though the natural substances with which the mineralogist deals all constitute parts of the crust of the earth, they yet include many a form that rarely or never comes under the observation of the geologist. Still, the exterior mass of the earth being formed of minerals in one state or another, the study of mineralogy is indispensable to the geological student.

The same may be said of chemistry, which now begins to throw a little light on some of the more obscure problems of

geology; as, for instance, the metamorphism of rocks, and the theory of volcanoes; a fine example of which may be cited in the beautiful investigations of Professor Bunsen, in Iceland, where some of the chemical processes consequent on volcanic action may be studied on the spot, thus aiding in the explanation of phenomena exhibited in volcanic districts of all geological ages.

The true bearing of the first part of these observations at once becomes apparent when applied to a passage in the history of geology. Before the time of Werner, more than a century was required to elicit the scattered facts and generalizations deduced by previous observers. Of Werner it might be said, that "his merit consisted in this, that he infused into the body of the science a new spirit."* The breadth of his views respecting the universal superposition of strata, his application of their structure to mining, and the eloquent sincerity with which he advocated his doctrines, raised an enthusiasm that spread over the continent of Europe, and gained numerous disciples to the cause.

This, perhaps, more than counterbalanced the prejudice suffered by our science in the promulgation of the erroneous hypothesis that the ancient rocks of every description were successively deposited over the whole earth, from aqueous suspension or solution in a "chaotic fluid." The very excitement roused by the bitter controversy maintained between the followers of Werner and the more philosophical disciples of Hutton, brought constant accessions of inquirers into the field, whose opinions, right or wrong, kept up a continued interest in the subject, till, weary of controversy, the very keenest advocates of the most exclusive Wernerian theories began to see the necessity of grounding their speculations on a more rigid examination of facts.

Of all the men that have heretofore illustrated the science of geology none is greater than Hutton, whose name was so long used as their watchword by the opponents of the Wer-

* Liebig's Letters on Chemistry, 1851. p. 26. Said of Lavoisier.

nerians. He at once threw aside the minor proofless speculations with which older writers bewildered their readers, and by the strict union of observation and generalization, his comprehensive mind grasped the main outlines of the physical section of the subject, and brought geology within the pale of inductive reasoning. Not a scrap of illustrative map or section, and but little of local description, accompanies Hutton's "theory of the earth;" and therefore, (harmonizing as they do with the detailed field work of later geologists,) his generalizations read almost as if dictated by a prophetic spirit—an impression not diminished by his massive and somewhat obscure diction. There wanted but one discovery to give that direction to the science which has led to the present high point of knowledge, I mean the doctrine of succession of species in time. Nevertheless, even had Scotland been a country geologically favourable to the easy development of that doctrine, it may be doubted, whether Hutton's mind was so modelled that it would spontaneously have entered on such an investigation. He perceived the great truth, that from the waste of continents, broad and thick contemporaneous deposits, containing the relics of life, are being formed in the seas, and that in all traceable past time the same laws have prevailed; but he knew not of the existence of a rule by which, independently of mineral character, contemporaneous strata may be identified, although widely separated from each other. The germ of this truth is, indeed, contained in the writings of an earlier writer (Fuchsel); but when he lived, the progress of discovery had not sufficiently prepared the way for its reception; and it is to the independent observations of that "great original discoverer" William Smith, that we owe the first clear enunciation of the law of the stratigraphical succession of species—a law alike great in theoretical results and in the strictly practical applications arising therefrom.

In the whole history of geology there is no chapter more touchingly interesting than the manner in which Smith arrived at his conclusions. From the moment the light first dawned on him, he never ceased to follow his convictions, with unflagging patience, industry, and energy, full of enthusiasm, undaunted by difficulties, or by the little heed that for many years was paid

him by the celebrated men, the results of whose subsequent work are in great part based on his discovery. "It plainly appeared" to him, that his "was to become a system of experimental philosophy that would embrace the whole surface of the globe."* Homely in exterior and manner, ungifted with the power of eloquent description, and averse to the labour of reducing his ideas to writing, few of his contemporaries would have dreamed of ranking William Smith as a man of genius: but posterity disregards externals, and judges men by their works; and I reverentially believe that in the truest sense of the term he well deserves the name. His clear-sighted sagacity, foreseeing the immediate application of local observations to world-wide areas, arose from a high combination of observing, inductive, and speculative powers—a combination of which the highest scientific genius is composed; his unswerving devotion, holding all other objects subservient to one great end, the heroic indifference with which he regarded all personal interests except in so far that they furthered it, his indomitable perseverance in the midst of difficulties and delays that hindered the production of his map of the English strata, all mark a man well worthy to be the first enunciator of a truth which in its consequences has opened to view a wide field for investigation that till his time lay utterly unapproachable. This grand and simple law, wedded to various branches of physical geology, already begins to "embrace the whole surface of the globe." This is what we are now doing. The "after ages" have already begun, when, as he predicted, we shall "get a tolerable description of the habitable world;" and on the further progress of this work of identification of strata, of mapping and of section making, depends at present most of the advancement of correct geological theory.

And here I would remark, that the results deducible from Smith's discovery afford another pregnant example of the economic application of purely theoretical principles, which in their first conception seemed but little connected with the furtherance of our material prosperity. In the expressive language of one

* Phillips's Memoirs of Wm. Smith, p. 10.

of my colleagues, "it is but the overflowings of science that thus enter into and animate industry"—a truth in the department of geology that I shall have occasion to illustrate in the sequel of this Lecture.

The right understanding of the law of superposition is not of value only to the man of science: it is important to every speculator in mines, to every landed proprietor who cares to understand the mineral value of his property; and the principles and greater laws pertaining to geological phenomena are now so distinctly understood, that there is no difficulty in imparting them to others. To draw an illustration from astronomy: we all know the truth of the revolutions of the planets and their satellites, of their general relations to the sun, of his relation to the fixed stars, of their motions in space, and of the dependence of their movements on the law of gravitation. Every well-informed schoolboy knows these things. We cannot all demonstrate them, but we believe in their demonstration; not alone that they do not contradict our experience, but principally by virtue of our faith in the men who have possessed a knowledge sufficiently high to solve the problems. Is it because geology as a science only numbers hundreds of years where astronomy numbers thousands, that beyond the pale of the student so much ignorance prevails regarding the simplest elementary principles and laws of the science, and that its cultivators are by many still looked upon as mere speculators; or, worse still, that others fancy themselves licensed to theorize without a particle of preliminary geological knowledge? Certainly not: true chemistry is but little older than geology; and no man fancies himself a chemist because he can *see* substances that enter into combination with each other. Not so with geology; without study, without training, without extended observation, and almost without reflection, many a man fancies himself qualified to decide on the nature and disposition of rocks (because they are before his eyes), whose decision is utterly worthless. If the leading features of astronomy are easy of comprehension, those of geology are more easily demonstrated, and but little less easy of understanding; the doctrines of superposition of strata, of succession of species in time, of disturbance of beds and consequent uncon-

formity, these and all other simple problems might (did there exist a race of qualified teachers) be made a part of every well-advanced schoolboy's education. Then, at all events, ignorant or mistaken men, misnamed practical, could not so readily delude the credulous or unwary into ruinous speculations: the iron-charged water of a spring, the colour of a rock, or the mere association of limestone and shale, might cease to induce explorations for coal among those who, hastening to acquire wealth, too often only precipitate their ruin; and I earnestly hope and believe, that not only by the aid of this School of Mines, but also by the more general spread of scientific education throughout the land, much may be done to prevent the frequent recurrence of so great a waste of energy and capital. To this particular end the more general diffusion of such authentic documents as the Government maps and sections will in time materially contribute, and much capital now wasted be skilfully applied, or diverted into other channels.

In Phillips's life of Smith several interesting notices are given of fruitless trials for coal in the Oxford clay, near Oxford and Wincanton. That at Wincanton was persevered in against the strong remonstrances of Smith. And here, instead of assuming a complete acquaintance in each of my audience of all the facts that bear on such cases (of which I shall cite other examples), you must permit me to explain one or two points that properly belong to a more advanced part of my course, but which it is now needful to point out for the full understanding of the subject.

I have alluded to the fact that the principal masses of strata were each in succession accumulated in sea bottoms; and these accumulations were composed of various sediments, just as at the present day quantities of mud, sand, and shingle are borne by rivers from the land, or torn from coasts and spread abroad on the floor of the ocean, to become the tombs of the creatures and plants that inhabit it. These beds have been, according to varying conditions, more or less consolidated, partially heaved above the waters, dislocated, invaded by igneous products, disintegrated, and denuded, their materials being often re-employed in the formation of later strata. And this process has been the course of nature through all traceable time. Hence it

follows that the rocks of continents and islands formed by such disturbances are necessarily of earlier date than the strata constructed from their wreck, and deposited in the surrounding seas; and the unconformity of one set of rocks to any other set will be proportionate to the amount of disturbance of the strata so upheaved, denuded, and often deeply depressed beneath newer accumulations. This unconformity was, as early as 1669, alluded to by Steno in his Prodromus, in which, by a series of rude diagrams, he sought to prove that the "country of Etruria hath been twice fluid, twice plane and dry, and twice scabrous and craggy." Strachey also had a faint knowledge of this fact as exhibited in his diagrams of the unconformity of the coal measures and new red sandstone of Somersetshire.* Our illustrious Hutton was, however, the first geologist who clearly expounded the laws of unconformity, and proved their universal application.

How, then, do these truths bear on the question, when, as in the instance recorded by Smith, sinkings were begun in the Oxford clay, the dark coal measure colour of which deceived the speculators and prompted the experiment? In the first place it is perfectly known, that excepting in the coal measures no coal occurs in any other formation in this and the surrounding districts. The sinkers knew this, for when they reached the oolitic limestones they abandoned the attempt. At what depth, then, had they persevered, might the true coal measures have been found? There is little reason to doubt that it would have been necessary to have sunk through oolitic and other rocks, (too thick to permit of such a speculation being profitable,) at the very least from 1,500 to 1,800 feet.

But even then there would have been no certainty of reaching the coal measures, for the newer rocks rest unconformably upon the older strata, and it is not improbable that owing to known disturbances other beds beneath the coal may rise towards their base at the point beneath the shaft.

It is forty years since this incident occurred. There are now sparsely scattered throughout England mining engineers of high

* Philosophical Transactions, vol. 33. p. 395.

attainments, well versed in the principles of geology; and the science is reaching a point when problems in economics may be solved far more obscure than those that tasked the knowledge of Smith; but you must not therefore suppose, that, as a general rule, many of our proprietors and speculators are guided by a higher knowledge than then prevailed. Such is not the case. Throughout the length and breadth of the land, down to this very day, equally fruitless and still more absurd undertakings are constantly being entered upon. I shall cite several other instances.

I have been informed that near Tiverton, in Devonshire, many years ago, a shaft was sunk in the shales of the millstone grit, an unprofitable set of beds at the base of the coal measures. As might have been foretold, nothing was found, till one Sunday, when the population were safely housed in church, some boys emptied a coal-scuttle into the pit, and on the top threw in part of the extracted rubbish. Great was the joy on Monday morning when the miners brought up the coal: it was declared to be "as good as Newcastle" (which indeed it was), and all the parish bells were set a-ringing!

On Chard Common, near Lyme Regis, they bored in the lias for coal, at an expense of several thousand pounds. The deception was fostered by the accident of passing through, not a *bed* but a *piece* of lignite. Numerous lias fossils were turned out, which of themselves ought at once to have decided the question, even without a broader knowledge of the geological structure of the country.

A similar trial took place at Kingsthorp, near Northampton, where a shaft was sunk through the lower oolite and lias, at an expenditure of near 30,000*l.* The adventurers desisted when they reached the new red sandstone. Many similar instances might be multiplied.

In the coal-field of the Forest of Dean the carboniferous limestone shale lies 1,000 feet beneath the lowest bed of coal. Nevertheless, in Herefordshire, a person, more confident than sagacious, first built his engine-house, and sheds to receive the produce, and then boldly sunk a shaft in these beds in search of coal, where it could not by possibility exist. In future lec-

tures I shall show that the coal measures once extended above this area, but the conditions never obtained by which one bed of coal could have been formed either in the beds explored, or in the old red sandstone on which they rest. At the very moment I now write I have received a letter from Mr. Aveline, one of the geologists of the survey, in which he says: "I have a narrow slip of coal measures running between the Permian, the new red beds, and the old red sandstone that you saw at Bewdley. A person found out the only place where the coal is well shown, and sunk a pit, but finding the coal worthless, *he has gone a little way off on the old red sandstone*, where he is sinking after the most approved manner, bricking his shaft round. He is going through some very hard sandstone." In this case the true explanation, of course gratuitously offered, was disregarded, and the last report announced by the "practical men" was, that they were on the very verge of discovering coal.

Observe in the vertical column, and in this horizontal section, the geological position of the lower silurian shales, utterly barren of coal, and sunk thousands upon thousands of feet beneath the coal measures, carboniferous limestone, and old red sandstone.* They are often black, and carbonaceous-looking, and their oozing springs are sometimes discoloured and scummy by the presence of oxide of iron, and other impurities derived in the passage of the water through the rocks. But coal measure shales are also frequently black, carbonaceous, and charged with numerous beds of ironstone, which, discolouring the springs, produce the red water (dwr goch) of the Welsh miner. By a mistaken application of the principle, that like causes produce like effects, the empirical miner sets to work, and the black slates of the counties of Pembroke, Radnor, and Caermarthen, —of Montgomery, Merioneth, and Caernarvon,—near Trefgarn, Caermarthen, Builth, Llanidloes, in Lleyn, and at Caernarvon, —are dotted with shafts, borings, and levels, sunk or driven in delusive searches for coal. While in progress, the cry still is, "the indications are good, go a little deeper;" and the pit, the

* Alluding to diagrams on the wall.

disappointment, and the ruin, often deepen together, till, abandoned in despair, the speculator is left to console himself with the parting assurance, "We are not to blame;—had you only gone a little deeper." Long after, when the wandering geologist visits such spots, he is informed that the miners actually found coal, but were bribed to hush it up by coal owners jealous of their markets.

I do not wish to imply that the men who advise such undertakings generally wish to deceive. Ignorance on both sides lies at the base of the enterprise. But on that very account, I repeat, that even a slender amount of science infused into the general education of the country would strongly tend to prevent the unceasing recurrence of such ruinous absurdities. The truly practical man,—the scientific mining engineer,—reasons and advises on very different principles. He is conversant with geological maps and sections; his experienced eye distinguishes the geological relations of the deep and wide-spreading strata of which a country is composed, and as a rule, he knows the utmost limits of the ground where it is safe to adventure; and, further, if he add to this a general knowledge of the organic forms that characterize these formations, a glance will tell him (however black the shale, or ferruginous the water,) that rocks containing graptolites, trilobites, lingulæ, and pentameri, were formed untold ages before the commencement of our carboniferous epoch.

It is foreign to my present object to trace the career of Smith in the application of his principles to agriculture, canal engineering, the interception of springs, opening of quarries, or the detailed determination of the position of coal bearing strata, concealed by overlying masses of new red sandstone. The immediate scientific results of his work* you see in this diagram, which exhibits his enlarged and corrected ideas of superposition, as understood by him, in the year 1816, and by this map, published in the previous year. This was the first geological map of England, or, indeed, of any kingdom, ever

* Smith's Column and Map.

produced,—a work in those days of extreme difficulty, when we consider that almost all the data were new and collected by himself; and that no large uniform topographical maps of authority then existed on which to depict them. Though propositions were made to the Government of the day, it yielded him no aid; the arduous work, wonderful in its kind, was accomplished by his own individual efforts; and it was not till many years later that, recognizing the national importance of a truly accurate survey on an adequate scale, Government established, under the direction of Sir Henry De la Beche, a geological survey of Great Britain in connexion with the Board of Ordnance. The survey then established, and since extended to Ireland, is now in full operation under the department of Works: the local direction for Ireland has been entrusted to Mr. Beete Jukes; the survey of England and Scotland is entrusted to my care, both being subject to the control of Sir Henry De la Beche as Director General. The basis of the survey is the Ordnance maps. A specimen of a portion of the work executed in England and Wales hangs on the wall, and when a sufficient area has been topographically surveyed, and other needful arrangements made, the survey will commence operations in Scotland.

On this extended scale, with a correct topographical basis to work upon, it is evident that a skilful geologist can lay down a multitude of facts in a style that, both for accuracy of general outline, and minuteness of detail, was formerly undreamed of by geologists; and I think I may be permitted to say, that great has been the benefit accruing, and yet greater will accrue, from this work, alike scientifically and economically. The boundaries of every formation, and of each of their subdivisions, of every igneous mass, intrusive or bedded, with all their accompanying intricacies of interstratified slates and volcanic ashes, the run of workable slates, of beds of freestone, limestone, and gypsum, every dislocation, metalliferous lode, and outcrop of coal, are traced with all that minuteness of detail admissable on this comparatively extended scale. These are accompanied by enlarged illustrative longitudinal and vertical sections, drawn in *true proportion*. As an instance

of their value, I would remind you that the broadest and deepest coal-field in Great Britain is that of South Wales. After the publication of the maps of that country, landowners, coal proprietors, coal viewers, and mining engineers, all acknowledged their importance; and I had the satisfaction of hearing the observation of a gentleman well versed in mining and scientific geology, "that the publication of the Government maps had placed them thirty years in advance of what they were before." I will be excused from the imputation of attempted self-laudation when I state, that that district was completed principally by Sir Henry De la Beche and Mr. Logan before my connexion with the survey began.

I shall give one other example of the application of geological principles to the solving of a question which will one day be of great economic importance: it is drawn from the work of the geological survey now in progress in the centre of England. As our sections in that country are still incomplete, I can only at present explain the principles on which our conclusions depend by means of diagramatic sections.

Underneath the true new red sandstone on the borders of Nottinghamshire and Derbyshire, is a strip of country noticed by Smith, but first fully described by Professor Sedgwick. He divided its rocks into magnesian limestone, and lower new red sandstone.* These rest unconformably on the coal measures, which they follow in the order of superposition. Owing to differences in lithological character, and the absence of the limestone, the Staffordshire, Warwickshire, and Shropshire coal-fields were long considered as unsurrounded by these beds. The upper new red sandstone was supposed to rest directly on the coal measures. By degrees, however, their existence in sundry places was noticed or surmised, and now on some of the smaller published maps indications of their existence may be found, both where they are, and where they are not. With a difference they are so exceedingly like the new red sandstone, that they have for the most part been confounded with it, at least

* The Pontefract rock, of Smith.

by almost all those engaged in the working of mines; and again, in some respects their mineral character here and there strongly resembles certain red portions of the coal measures. They are, therefore, in most maps sometimes incorrectly delineated, but distinguished from,—and sometimes erroneously included in, the coal measures, or new red sandstone, as the case may be.

It chanced, however, last year, that by dint of constant practice and study in the field, my colleague, Mr. Hull, discovered a key to the separation of these rocks from any others of the district; and the progress of the mapping of the country has shown, that everywhere, except in accidental cases, they rest unconformably on the coal measures, and that the new red sandstone is unconformable on both.

Now, for reasons that I cannot at present enter upon, it is known to geologists that concealed treasures of coal probably underlie the larger portion of the great area of new red sandstone that surrounds the coal-fields of central England. Already in great part of South Staffordshire most of the best beds of ironstone are being rapidly exhausted; and in great part of the district "the thick coal" has been extracted, or the workings are so drowned by water, in consequence of the faults being worked through by gate-roads, that its drainage is next to impossible. The day will surely come when this and other coal-fields will be worked out; and the question will then arise, at what depths beneath the unconformable covering that shrouds them, will coal-bearing strata be found in various localities? This is an important problem, which the work we are now engaged upon will go far to solve.

By means of numerous observations of the dip of strata, and the construction of sections on a true scale, it is often possible to determine the thickness of any special mass of rocks. Within a given area, where, therefore, is the new red sandstone likely to have the smallest thickness? or, in other words, where can we predict that the concealed coal measures rise nearest to the surface?

In this diagram you will observe that the lower new red sandstone, or Permian strata, rise against the coal-fields on the east

and west, and that the whole is overlaid by the upper new red sandstone.* It is therefore to be expected, that in this district, the lower new red sandstone, strata intervene between the upper new red sandstone and coal measures throughout. This suspicion is confirmed by the circumstance, that within the new red sandstone area surrounding the central coal-fields of England, many miles removed from these fields, the beds that elsewhere rest directly on the coal measures are brought to the surface by faults.

'If the estimates of thickness be correct, then no wise man would sink in this area on the new red marl, because, before he could reach the coal measures, he would have to penetrate the aggregate thickness of three formations, viz., new red marl, upper new red sandstone, and the lower new red sandstone or Permian.

To the unpractised eye, these last seem ordinary new red sandstone. ' In this area they were confounded with it. But a rigid geological examination has shown that they belong to a lower set of beds, and that faults at certain points raise them to the surface; and these may be proper places in which to sink in the hope of finding coal, because the concealed coal measures must also be raised nearer the surface by the faults, and therefore in the search, we escape many hundreds of feet of rock that elsewhere overlie the strata to be sunk in

There is yet another point of interest in connexion with this subject. I have stated, that the new red sandstone proper rests unconformably on the lower new red strata. It therefore often happens, that overlapping the latter it rests directly on the coal measures. The result is, that at a distance from the carboniferous strata, it is possible to estimate the probabilities as to whether in sinking through new red sandstone, we might reach the coal measures without the intervention of thick masses of lower new red or Permian strata.

These are questions that daily assume a higher importance. The attention of proprietors and miners already begins to be

* Illustrated by a diagram of the disposition of the strata round the South Staffordshire and Coalbrook Dale Coal-fields.

directed to them, hitherto in general without much effect, chiefly for want of accurate geological information. The value of land will be materially affected in certain districts by the information yielded by such maps and sections.

If you compare a distorted section with one across the same country drawn on a true scale, you will readily perceive one of the causes of the indefinite ideas often entertained on such subjects. In one the distances are diminished, the heights absurdly exaggerated, and the disposition of the strata therefore necessarily falsified; in the other, a true corresponding scale for distance and height being adopted, the lay of the beds as they actually occur in nature is obtained, and the conclusions arrived at are precise and definite. On me devolves the responsibility of instructing the pupils in the School of Mines in the methods by which accurate geological maps and sections are constructed; and it will be my duty to do so, not only in the lecture room, but also through the medium of the districts in progress on the geological survey, to convey practical instruction in field work to those of our mining or engineering students to whom such knowledge may be indispensable.

It would be easy to show many other applications of geology to practical purposes, as, for instance, in the construction of roads, and the selection of material for macadamising, in the engineering of canals by leading them over naturally tenacious bottoms and the avoidance of porous formations, in the selection of minor deviations of lines of railway with reference to cuttings and tunnels, and also in the sinking of shafts. An instructive instance connected with shaft sinking came under the notice of Mr. Bristow of the geological survey. On the Ridgway tunnel a shaft was sunk through 80 feet of sand, which rendered it necessary to brick the sides, whereas a few feet further in either direction would have carried the shaft safely through the chalk. The sinkers had, in fact, chanced to sink in one of those holes in the chalk known to geologists by the name of "pipes." These are always of small diameter, and probably originated in the percolation of rain water, the carbonic acid having carried off the lime in solution; they afterwards became filled with foreign substances, *in* which, in this instance, they sunk.

A knowledge of this simple fact would have prevented the blunder.

The agricultural applications of geology have been ably treated by Mr. Trimmer; and its bearings on large supplies of water to towns are beginning to be universally recognized. The country around and beneath London affords a tempting field for enlarging on this subject, but at present I shall rather refer to the construction of the artesian well at Grenelle, principally because it was undertaken and executed on data and principles purely geological.

In earlier times the phenomena of springs gave rise to much discussion. While some considered that they originated in great subterranean reservoirs, others asserted that they were due to the percolation of sea-water which flowed upwards by subterranean cavities, losing its saltness in the passage. More than a hundred years ago, Valisnieri partly explained their dependence on the fall of rain, and the nature and arrangement of the strata through which the water percolates. Since his day, the theory of springs has by degrees come to be well understood, and from the time of Smith, by strict attention to geological data, it has been possible to estimate with almost absolute certainty the results of sinkings in search of underground water in numerous localities.

Rocks are of many degrees of hardness, and variously disposed. Thus, for instance, granite and its igneous allies, are but slightly porous, and it is only through joints and cracks, generally of no great depth, and having little intercommunication, that the surface water can penetrate; and thus the subterranean oozings are isolated, so that generally no great body of underground water is anywhere collected, and numerous feeble springs rise here and there to the surface. But it is different with many of the stratified rocks, which not only by a multiplicity of joints, but also from their extreme porosity, and the sloping disposition of the beds, are often perfectly adapted to the conduction, and partial retention, of large bodies of water, at depths varying with the disposition of the strata.

The nature of artesian wells is simple. If I take a bent tube and pour therein any quantity of water, it will maintain a corre-

sponding level on either side; and if I insert another tube shorter than the curved arms, (we shall suppose at the lowest point of the curve,) then, by virtue of a law of hydrostatic pressure, the water will rise in the inserted tube, an equal amount being displaced in the curved arms on either side. There it will rest. But if a constant supply be yielded to one or both of the openings of the curved reservoir, then the water will overflow at the mouth of the central inserted tube, which thus represents the boring of an artesian well.

The strata around Paris are in a general way very similar to those forming and surrounding the London basin, (as it is often termed,) with which many of you are familiar. Its highest members are composed of tertiary strata of sand and calcareous sandstone, beneath which are beds of mottled clay. The chalk on which this lies is 1,477 feet thick, resting on 150 feet of green sand, which in its turn lies on the gault. This last is for the most part composed of clay, and nearly impermeable to water. The whole over a width of many miles is arranged in the form of what geologists term a basin, that is to say, the strata from their outcrops have a tendency to slope towards a general centre, where for a space they lie more or less horizontally.

On the margin of the basin, strata of green sand and gault rise to the surface at heights in many places approaching to 330 feet above the sea, Grenelle being only about 100 feet above that level. Geologists knew that the water which fell on these strata at their outcrop would of necessity percolate in the direction of the inclination of the beds, so that, at the lower points of the curvature, a great body of water must exist, confined as it were in a sponge, and unable to escape below, because of the impermeable quality of the beds on which the porous strata rest. This deep-seated reservoir being tapped by boring, the water would rise to the surface in the manner I have explained.

In 1832 the municipal corporation of Paris, impressed with the sanitary necessity of further supplies of water, voted 18,000 francs for the construction of three artesian wells—a sum so ridiculously small that the project was immediately abandoned. M. Mulot, however, one of their engineers, having previously

sunk in the chalk at Suresne, at Chartres, and at Laon, to the depth of 1,082 feet, proved that it would be necessary to bore completely through that formation to ensure a sufficient supply. This conclusion, based on strict geological reasoning, was confirmed by M. M. Arago and Walferdin, and in November 1833 the work was begun. With infinite energy, skill, and perseverance, M. Mulot carried it on, overcoming every opposition, physical and moral; for he had not only to conquer those natural difficulties that beset so unexampled an undertaking, but he had also to contend with municipal parsimony, that shrank from the continuance of supplying funds for a project based on purely theoretical grounds. When he reached the depth of 1,640 feet, at an expense of 263,000 francs, they stopped these supplies; but so great was the faith of M. Mulot in the correctness of the principle involved, that he determined to continue the work at his own charges. On the 26th of February 1841, the borer suddenly fell several yards, and immediately, from a depth of 1,800 feet, there sprang from the orifice a huge column of water, cold at first but warm afterwards. It now steadily yields more than 740,000 gallons per day. At the first burst the supply was greater.*

These are some of the subjects to which geology lends its aid in promoting our material prosperity, comfort, and health. But its bearings in many other directions extend far and wide. Physical geography, for example, is in reality a branch of geology, for the present forms of sea and land are but the result of all the geological changes to which our globe has been subject, and existing forms of vegetable and animal life are to the present world what the fossil forms in the rocks (and many more unpreserved, or that may never be disentombed,) were to the scenery of the lost continents and islands of bypast epochs. Viewed in this light, geology connects itself with the more graceful arts that at once adorn and elevate society, and that quite independently of the beautiful mineral substances yielded by the rocks for purposes of art. It becomes of value to the

* See Le Puits Artésien de Grenelle, par M. Rey. Paris, 1843.

artist, for it cannot be quite unimportant to him that he should be ignorant of the origin of the infinite diversities of scenery, of the great operations that have given distinctive features to every plain, and hill, and mountain crag. In many a depicted scene, however skilfully coloured, the geologist who has an eye for art sometimes detects improbable forms or combinations. The sculptor and the historical painter may not safely be ignorant of anatomy, and on the same principle it cannot be a matter of small moment, that, merely copying externals, the landscape painter should be utterly ignorant of the inner anatomy of the scene; for I cannot but believe, that a certain knowledge of this structure will go far to give the impress of a vivid reality to the landscape he delineates, when, abhorring conventional forms of rock and mountain, he, in his compositions, bearing in mind the actual value and relation of all the parts of a landscape as composed by nature, transfers to his canvas the truthful impressions of a well stored and cultivated mind. It is this perfect truthfulness that often lends so exquisite a charm to the works of the greatest English landscape painters of modern times, whose mountains and rocks are so true that the geologist can often pronounce their very nature and their names.

I must now close. In succeeding Lectures it will be one of my aims to inculcate that a sound knowledge of theory is indispensable towards all the applications of geology, whether economic or otherwise. Let not any man consider that when he has mastered the few facts that may be immediately turned to account in money getting, that his geological education is complete. The men who first educed all our great results were mainly actuated by the love of truth alone; and the applications are an accidental fruit of that love. On every possible ground it is, therefore, worse than impolitic to undervalue any truly philosophical work of the geologist, whether it be shown in the unravelment of geological intricacies in the mountains, or in abstract studies in the closet. As a point of conscience actuated by these principles, it has been the aim of those engaged on the geological survey to carry accuracy of scientific detail to the extremest possible limit; and (independently of any immediate benefit to science and to the owners of the soil) who can predict

what may yet arise to further the arts of peace from such labours, even in districts apparently the most unprofitable? Let no geologist, therefore, be discouraged because of the sneering cry *cui bono*. The true man of science will not heed it; and hitherto geologists have pursued their ends unscared.

No people has produced so many men eminent in geology as the British Isles. Though not the birth-place of geology, it is here that it has been principally fostered and reared to its present goodly stature, within the memory of many yet living. Of the illustrious men who aided in this work some have passed away, but others still remain among us; and difficult as it may be to follow in the footsteps or to emulate the "large utterance" of these early giants, I earnestly hope, albeit the signs are few and meagre, that a race may yet spring up not unworthy to be their successors. The links that bind primeval time to our own have to be sought out,—the history of a world has to be unravelled. The alphabet has been discovered, and some of the inscriptions graven on the rocks are deciphered; but many readings are wanting, many passages obscure. The time is still early, the subject is but opening to view, and its revelations are boundless. Hitherto there has been a wonderful unanimity of purpose among all true cultivators of geology. The advance of geology, through the friendly co-operation of its votaries, has known no pause since the decline of the Huttonian and Wernerian controversy. The physical structure of our country is one cause of this rapid progress, but the earnest character of the men who investigated that country is another secret of the strength that has so rapidly urged the science onwards; and I earnestly trust and believe that that strength will know no decay while the rising cultivators of geology continue worthily to follow the bright example set by their great predecessors.

On the Value of an Extended Knowledge of Mineralogy and the Processes of Mining. (*Being the Introductory Lecture to the Course of Mineralogy and Mining.*)

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Πολλαὶ τέχναι ἐν ἀνθρώποις εἰσὶν ἐκ τῶν ἐμπειριῶν ἐμπείρως εὑρημέναι· ἐμπειρία μὲν γὰρ ποιεῖ τὸν αἰῶνα ἡμῶν πορεύεσθαι κατὰ τέχνην, ἀπειρία δὲ κατὰ τύχην.—*Plat. Gorg.* (*Polus.*)

There are many arts among mankind which have been invented by the experienced, through the means of experience: for whilst experience causes our age to advance by the principles of art, a want of it leaves us dependent on chance.

HAVING been honoured with the charge of opening in this Institution a course of instruction on Mineralogy and on Mining, I deem it desirable in the outset to define the limits of these distinct although kindred subjects, and to point out the directions in which they dovetail into the other branches of applied science as treated by my colleagues. The technical character of the education to be imparted here will be the beacon which I shall endeavour to keep in view, that I may avoid being drifted by the current of thought too far into the wide expanse of general considerations, where in connexion with those studies so much that is beautiful and useful in ordinary life has already been acquired, and so much still remains to be discovered; but where in the meanwhile we might wander wide of the desired path. This discourse will therefore deal almost entirely with matters of practical application; and a number of examples which have been brought under my own observation during a few years past will be adduced in support

of the proposition—that *an extended knowledge of mineralogy and the processes of mining are essential to those interested or engaged in mines.*

In the commencement of an inquiry into the infinite variety of objects surrounding us in the natural world, presented, it would appear, for the purpose of inducing the most attractive and holy exercise of our observing and reasoning powers, it is obvious that three principal assemblages are to be discriminated. These divisions are the animal and vegetable kingdoms, characterized by organic structure, and the wondrous phenomena of life; and the inorganic or mineral kingdom, comprising that far greater proportion of the materials of the planet in which no traces of organic structure are observable. This last assemblage of objects has been generally understood to form the province of mineralogy, which thus in its most extended sense would include all the aëriform and gaseous bodies occurring in nature, and could hardly venture to exclude the multifarious substances produced under similar chemical laws by the agency of man.

But since, amid the daily increasing accumulation of new and unexpected combinations, the domain of the inorganic kingdom appears unlimited, and many of its phenomena must be investigated by special departments of science, it becomes necessary to draw a boundary line around that portion of it which is to be embraced in modern mineralogy; and where we can find no logical distinction between the actual products of similar bodies and similar laws, as seen in nature or in art, we must, for the sake of convenience and utility, rest our criterion of separation upon the different conditions of their origin.

Under this point of view mineralogy has for its object the consideration of the natural inorganic materials of our globe, fluid and solid; the physical phenomena which they present, their chemical constitution, their modes of occurrence, the methods by which they are distinguishable from each other, their classification, and the uses to which they may be made subservient.

Now it is evident that as the characters of minerals are dependent partly on their form, partly on their chemical and partly on their physical properties, mineralogy must be based upon geometry, chemistry, and natural philosophy; and the

history of the science affords the best proof that no branch of knowledge can rise towards perfection till the conterminous sciences have, after due cultivation, been brought forward to aid in its development. The student should therefore previously acquire a certain acquaintance with these auxiliaries; and it is for this reason that the lectures on chemistry and physics have been so arranged as to precede the more compound subjects on which we are now about to commence.

It may at first sight appear trivial and unnecessary to insist on the definition and objects of mineralogy; but, in addition to the importance of a clear understanding of the purport of any branch of education, there are in the present case special reasons for adopting such a course. This science has in Britain, for many years past, been cultivated by so small a number of investigators, that by the public at large it has been almost lost sight of, and is not unfrequently confounded with chemistry, geology, or metallurgy. Nay, there are not wanting among scientific men those who assert, that as a mere department of chemistry it can hold no independent place, nor offer a foundation for a special course of study. The above definition, however, may aid in fixing its true position, and will show, that whilst we contend with such opinions on the one hand, we would oppose on the other the vain struggles of those who have endeavoured to disconnect the science from that chemical aid which has so much advanced its progress and heightened its interest.

The prime and grand interest attached to our studies of the products of the earth is to be found in the fact that the mineral properties of different lands, in conjunction with their geographical features, have determined the distribution, the physical and social character, and the well-being of the various races of man. Whether we examine the vestiges left by the peoples of gray antiquity, or study the modifications produced in branches of the same race located in regions of different aspect, or inquire into the origin of the chief seats of modern civilization, we shall be assured that most of these phenomena are dependent immediately, or through the medium of vegetation, on mineral produce, and the particular conditions under which it can be made available to human convenience.

In the remains of ancient Egypt we learn how a stupendous architecture arose by the aid of the soft yet massive sandstones piled by nature on the banks of the Nile, and how monolith statues and obelisks were suggested by the presence of a syenite capable of taking a high polish, and admitting of the sharpest intaglio tooling. In Attica the marble of Pentelicus and the silver of Laurion combined to develope that high state of art which, exemplified in the Parthenon and the sculptures of Phidias, has never since been equalled; whilst the abrupt limestone ravines of Lycia and Arabia Petræa gave rise to a description of architecture peculiar to itself.

As examples of the second point, call to mind the different occupation and character of the dwellers in the Spanish peninsula,—the active mining and mercantile population of Gallicia, Asturia, and the Basques on one hand, the indolent Castilian and Portuguese on the other.* Or compare the torpid millions of the Slavic race in the plains of Russia with their industrious relatives and co-religionists in Servia and Bulgaria.†

Lastly, in furtherance of the third inquiry, we need only to examine the beautiful population map of the British Islands by Petermann, which shows at a glance that besides the conditions requisite for the purposes of shipping, it is coal and iron and lead and copper that mainly influence the increase of our towns. Nor can we omit to refer to the amazing process by which the discovery of gold is at this day pouring a new tide of population over parts of Siberia, to Western America, and to the Antipodes.‡

Such general views are, however, somewhat foreign to my purpose; for the main question which lies before me is the importance of mineralogical knowledge to those engaged in technical avocations. Enormous as is the interest at stake in

* Le Play, Ann. des Mines, 1834.

† C. Weerth, "Die Entwickelung der Menschenracen durch Einwirkungen von aussen." Lemgo, 1842.

‡ Virlet, "Coup d'œil statistique sur la Metallurgie dans ses Rapports avec l'Industrie, la Civilisation, et la Richesse des Peuples." 1837. Ami Boué, "Der ganze Zweck und der hohe Nutzen der Geologie." Wien, 1851.

connexion with this science, it is obvious that a more or less profound acquaintance with its facts must be productive of considerable differences in the progressive development of the national wealth. It is surely patent to all that the miner ought to be thoroughly acquainted with the nature of those substances which it is his daily task to seek in the recesses of the earth, as well as with those which exert a favourable or a pernicious influence either on the abundance or quality of the objects of his search. No less should he be prepared to recognise those which, although unusual in the spot where he has commenced his career, may be thrown in his way either in another part of the same vein, or in neighbouring veins of the same district, or even in other lands, to which, by the varying demands for mining skill, he may so probably at some time be transplanted.

Supposing even that our miner had perfected himself in a science requiring far more close application to books and in-door study; supposing that he were an expert chemist, I venture to assert, that although in many cases highly serviceable to him, this rare acquisition would not make amends for an ignorance of mineralogy. Were he, each time that he required to know the nature of a substance, obliged to enter upon its chemical analysis, his days and years would be passed in endless labours often repeated and sometimes fruitless. If we concede that after twice or thrice analysing the same ore, for example, he were to recognise it the fourth time by some less laborious test, we allow, in other words, that he has acquired a mineralogical knowledge of that single substance: and thus we arrive at the conclusion, that the methods of mineralogy are those which a man must employ, if, in relation to the natural inorganic bodies, he desire to reap the advantages offered him by previous investigations.

There exists, it is true, in practice a source of difficulty which has probably gone far to prevent the spread of our science. Whilst many of the more abundant and valuable productions of the mineral kingdom are met with in such a state of impurity from mechanical aggregation and admixtures, that the particular minerals of which they are composed are not separable by physical means, others occur only in an amorphous or irregularly shaped condition. Now scientific mineralogy bases its descrip-

tions on the most perfect individuals, or crystals, of each species, bodies which are comparatively rare; and treats with but little respect those which are never crystallised, and of which the distinguishing characters are less definite. It stands to reason that in an Institution of a practical tendency the strictness of such rules must be relaxed, and that greater weight must be attached to those substances, chemically impure though they may be, which are abundantly yielded by our mines and quarries, and yet scarcely constitute true mineralogical species.

We shall thus, for example, study the characters of the pure carbonate of iron in the crystals occasionally lining the cavities of our lodes, in the masses which exert so powerful an influence on the industry of Nassau and the Austrian Alps, and again in those indefinite mixtures which as nodules and continuous beds have, from their geological position and abundance, contributed in a high degree to raise Great Britain to her present pinnacle of manufacturing power.

But the cause of such a preference in mineralogical works is at once evident, on comparison of the objects described with those of the other classificatory sciences.

In the animal and vegetable kingdoms the naturalist traces, in successive groups of animals and plants, a descending scale of lower and lower organization, till at last, in the most rudimentary forms of life, individuality is lost in an assemblage; yet down to this point each species presents none but forms complete in themselves, and almost unvarying. In the mineral kingdom, on the other hand, we are obliged to seek out for description the most perfect specimen, because it is not a succession of species, but the same species which offers a never-ending diversity of aspect. The mineral species may indeed occur in every state of development, from the symmetrical crystal, composed of definite constituents, passing through every grade of incompleteness of form or admixture with foreign substances, till we reach the lowest step of the scale, where the individual is so merged in the mass that form is destroyed, and the other characteristics are no longer discernible to the sense. How striking is the parallel in human societies, where the development of mind and resources unmistakeably accompanies such arrangements as lead to the

self-reliance and importance of the individual, whilst as surely the crippled freedom of action caused by merging individuality in the crowd is attended by deterioration and destruction of all healthful prominences of character!

But besides the miner, there are hundreds and thousands amongst us whose pursuits, bearing on the practical purposes of life, render a knowledge of mineralogy an element of success. The geologist, the engineer, and the architect must have recourse to mineralogy to gain acquaintance with many of the materials which they employ; nor, even if they possessed unlimited time and means for the acquisition of chemical analyses, could they afford to overlook the physical properties which are often chiefly instrumental in fitting those substances to their several applications. The agriculturist, if he wish to modify and improve the condition of his soils, must become familiar with the appearance and qualities of the marls, limestone, gypsum, phosphorite, and other minerals, which are now beginning to exert a remarkable influence on his art. The antiquary, without a knowledge of the stones from which the ancient inhabitants of the earth sculptured their idols, reared their temples, or fashioned their rude implements, and of the ores from which they produced their metals and alloys, can draw no sound conclusions as to the comparative civilisation of distant epochs, nor guard himself from the blunders consequent on faulty observation or crude description. Who, again, that is not insensible to the varied beauties of the brilliant gem, would hesitate to prefer to determine its nature by the methods of mineralogy instead of entrusting it to the chemist, who, with ruthless hand and devouring acids, must destroy its substance ere he can pronounce upon its character?

Other and numerous mineral productions there are for a decision on whose value we are dependent on the aid of analysis. Among the irregularly mingled bodies to which I have before alluded are many which, like the iron ores lately discovered in the oolitic formation, can only be determined as to their importance by accurate assay. Few among the crowds who at the late Industrial Exhibition swept by the series of iron ores brought together from all parts of Britain by Mr. Blackwell, could have prophesied that the collection of half a dozen of those

sombre stones would give rise within a few months to an active industry, which bids fair to develope a new phase in the gigantic phenomenon of the British iron trade. An example, this, of the mutual dependence and assistance of three sister sciences, where geological reasoning had to point out the tract in which a given formation was to be found, mineralogical observation to discover the actual deposit, and chemical analysis to determine the value of the ore.

The mining districts of Great Britain are so utterly destitute of the means of mineralogical education, whether in schools or suitable collections, that it need be no source of wonder to find the most intelligent miner acquainted only with some two or three of the substances, which in the routine of his employment have been brought prominently before him, and often neglecting others from ignorance of their nature, or dangerously confounding things which are totally distinct from each other. It is matter of history that the copper ores of Cornwall were recognised as useful only at a comparatively late date, the miners having concentrated all their attention upon the tin with which that county was so plentifully supplied. More wonderful does it appear, that even at the commencement of the last century, when the yellow ore or pyrites had been long appreciated, the far more valuable redruthite, or sulphide of copper, was thrown as worthless rubbish over the cliffs of St. Just into the Atlantic; and Pryce informs us, that "many thousand pounds worth of the rich black ore, or oxide of copper, was washed into the rivers and discharged into the North Sea from the old Pool mine."*

These might be considered as the errors of a past age, but we may recollect that they occurred at a time when the value of the same substances was understood in other countries; and by mere accidental rencontres similar cases are still not unfrequently brought to our notice.

During a visit, three or four years since, to a mine which was supported chiefly by raising blende, the sulphide of zinc, my attention was attracted by a lump of white mineral lying on the window-sill of the office, a single glance at which was sufficient

* Pryce, Mineralogia Cornubiensis, 1778.

for recognition; and I put to the agent a few questions regarding its nature and occurrence. He replied that it was nothing but "spar", and that in working a particular part of the lode they had met with many tons of it, which, however, had been all, except this accidentally preserved specimen, irretrievably mixed with the rubbish heaps. The surprise of my informant was not small, when he learned that the so-called "spar", confounded by him with quartz, was calamine, an ore containing in its pure state above 60 per cent. of oxide of zinc. Not to leave the same metal and its ores, which put on a great variety of characters, I have known zinc blende taken for lead ore, and honoured with the erection of a smelting furnace, when, to the chagrin of the manager, the volatile metal flew away up the chimney, leaving only disappointment and loss behind. Again, from a faint resemblance which some of the varieties bear to certain iron ores, a resemblance which would at once disappear before accurate observation, a considerable quantity was bought, not long since, by one of the greatest iron-masters in this country. It was carried to the furnaces, duly mingled with fuel and flux, and after a strenuous effort had been made to get it to yield iron, it all, as the proprietor naïvely remarked, "went off in smoke."

Blunders of this kind are more excusable when made in regard to some of the minerals of comparatively rare occurrence. An active agent of my acquaintance, a man of high character, was requested by a couple of his friends, who gave themselves credit for uncommon sagacity, to join them in forming a company to work a deposit of an unusual ore which they had lately found. Already they had referred it, for corroboration of their opinion, to a person at Birmingham styling himself a mineral chemist, whose report set forth that the specimen shown him was, as the others had suspected, an ore of molybdenum, and that it was worth 8*l.* per ton. This was sufficient to induce the agent to join the discoverers in a journey to the place in question, and at the head of a remote valley, embosomed among the rugged hills of Cambria, he was gratified with the view of such a mass of the same substance that it was evident that thousands of tons might be quarried at a mere nominal price. Specimens were broken, the party returned to consider the preliminaries of their adven-

ture, and it was agreed that the mineral corresponded pretty nearly with the description of sulphuret of molybdenum in some book, which was at hand. Still, the more cautious manager feared that the prospect was too bright to be real, and without consulting the others, expended a fee in sending for a good analysis to a scientific chemist in London. The result was, that the substance in question proved to be a shining, black, slate-clay, not applicable to any use, except perhaps to make bricks.

Within a gunshot of the place where the above-mentioned agent related this anecdote, the appearance of some rather ferruginous slate rock attracted the attention of a party of credulous speculators, who believing they had discovered a rich iron ore, actually built a blast furnace, erected the necessary machinery, and continued for some time to carry out their vain attempt, deluded by the fraudulent practices of the workmen. As might, however, have been predicted, the undertaking soon ended in abandonment and ruin.

In other mining districts I have known persons, who although possessed of great general intelligence, have collected blue stones (generally ores of copper) for cobalt, ignorant of the fact that none of the natural combinations of this valuable metal possess a blue colour.

The sulphate of baryta has for a few years past borne a certain value for manufacturing purposes; and an instance was brought to my notice, where a ship-load of what was supposed to be this mineral was obtained by surreptitious means, and sent from a distant part of the country to London. But the biter was bit, for his observation was faulty, and his cargo, proving to be calcareous spar, was worthless. It would tire out your patience to enumerate the cases in which mica or iron pyrites have been mistaken for gold. From the anxious country gentleman in our own land, to the disappointed Californian gold seeker, and to the solemn Turkish Bey mysteriously unwrapping from many a folded rag the specimen of his expected wealth, such victims of mineralogical ignorance are frequently presented to those whose pursuits bring them into a position for advising on similar points.

But there is another and a wider field far more important

than the correction of isolated mistakes, in which mineralogical research has yet to be largely employed, and in which the connexion of this subject with mining is no less grave than intimate. The principles by which the accumulation of ore in lodes or metalliferous veins has been regulated are to this day so enveloped in mystery, that the prosecution of mining enterprizes is almost as much a matter of chance as it was with our forefathers three centuries ago. Nor can we wonder that this should be the case, when we regard the peculiar difficulties by which the subject is beset. Not only is the progress of the operations so slow that the observation of one set of phenomena may extend over many years, but the examination of some points, unless made at the time of first opening, is precluded by the discolourations of water and powder smoke, or by the means adopted to secure the works. Then, according to the conditions under which the lode is placed, a combination of problems, geological, physical, and chemical, are presented for solution, and the thoughtful mining agent, left to consider them only by the light of a partial experience and natural shrewdness, is commonly led to see them through a peculiar medium, and to fall into the numerous errors resulting from unsound premises. Copious stores of knowledge have, it is true, been acquired by many of the captains and tributers in Cornwall and elsewhere; but besides the difficulty, according to the various views of individuals, in collating them, they have generally, from want of early educational opportunity, been accumulated upon an unsafe basis; and finally, the experiences perish with the men, leaving society no richer for their acquisition.

Nowhere is there more room than in the study of this subject for accurate mineralogical observation,—nowhere is the prize offered more inviting; for the resolution of some of these questions must tend to acquaint us with the probability of finding remunerative ores in certain directions, either in depth or on the course of the lodes, and must, therefore, be instrumental in discovering untold sources of wealth. Nor need we despair, when we remember the confused state of all the natural sciences little more than a hundred years since, that at some future day a more systematic cultivation, by rigorous induction, founded on

close observation, will clear away the weeds, and cover with plenteous crops this hitherto barren field.

We are thus naturally led, by the contemplation of the objects to be sought for, to the second part of our subject, the Art of Mining: and here it will be necessary to dwell at greater length on the character of the studies which it is desired to embrace, inasmuch as no course of instruction in them has yet been attempted in this country; and, strange to say, not a single book exists in the English language in which they are comprehensively treated. Among the Germans many excellent works on mining have appeared from time to time during the last three centuries; and even in France, a country comparatively so poor in mineral productions, treatises have been published, in which many of the divisions of the subject have been skilfully discussed, whilst the periodical literature of both those nations is rich in detailed descriptions of the natural phenomena and the working processes of mines in all parts of Europe. Nor are we unindebted to the Russians, whose well-educated officers of mining engineers, sent at the public expense to investigate various mineral regions of the continent, have carried back with them a treasure of valuable information, which has been in a great degree instrumental in advancing, to a high grade of perfection, the mining and metallurgical operations of the Ural and of Siberia. In Britain, however, we have little else than two or three treatises on the working of coal, and a few isolated papers on other parts of the subject; and hence it will be needful, in a series of Lectures, to depend in great part on personal experience, and to indicate, in exceptional cases, the sources whence a knowledge of details may be obtained.

But it would be an injustice to the many thinking and enterprising spirits among our British miners not to express our admiration for the skill and ingenuity which they have brought to bear on particular portions of their art. Surrounded by difficulties and dangers, they have won enduring triumphs; and in some of their applications have, by the force of persevering industry, advanced their experience with such rapid steps, that science has been glad to follow in their wake, and reap new facts to aid her further progress.

The first great feature which strikes the attention in approaching this subject is the enormous value of the mineral productions of Great Britain, amounting, as has already been stated by our honoured Director in Chief, to the sum of 24,000,000*l.* annually in the rough state. So bountifully, indeed, has our country been enriched by Providence with these sources of wealth, and in a degree so much higher than any other region in Europe, that it need excite no surprise if those natural gifts which even aroused the industry of the early Britons, and excited the cupidity of their Roman conquerors, yield at the present day an amount of riches far greater than those produced by any other nation. Let us, then, consider the great population supported directly by the extraction of these minerals, and indirectly by their application to the arts,—the maintenance of hundreds of thousands of men by these not inexhaustible stores,—and the entire dependence of our whole manufacturing and commercial system on the supply of fossil fuel; and we cannot fail to arrive at the conviction, that in exercising the stewardship of such gifts of Heaven, the nation has a high and responsible duty to perform, that waste and improvidence are a national sin, and that it behoves all who are in any way connected with the working of our mines to lend their best endeavours to the perfecting of the most economical and efficacious means of rendering all the products of our mines available to the uses of mankind.

It is not pretended that by any plan of education in an Institution of this kind, it is possible to make a miner, or in other words, to prepare a man for taking charge of a mine as soon as he has left our walls: not more reasonably should we expect that a lad drilled in the classes of a naval college were at once metamorphosed into a sailor, fitted at once to take command of a ship. Yet surely no one will deny, that if in that school he has learnt to box the compass, to knot and splice, if he has worked out problems in navigation on sound mathematical principles, if he has been taught by descriptions how to handle a vessel at anchor in a tideway, or on a lee-shore, he will be infinitely more ready to take advantage of circumstances, and to make rapid progress, than if he had been sent

on board unknowing of these things and their principles. No "royal road" to learning, no legerdemain of "cramming," can make amends for the want of time and pains bestowed on the acquisition of practice; and as with the seaman so should it be with the miner.

By description, by drawings, and models, it will be our endeavour to make the student familiar with the chief phases of the operations practised in various regions, and under different conditions. He will have, each year, the opportunity of closely inspecting the mineral features and particular mining processes of the districts under examination by the Geological Survey; and, when furnished with this preliminary knowledge, will, I doubt not, pass to his sphere of probation better qualified to observe and to compare; whilst the practical experience which he must afterwards acquire will be superadded to what he has already benefited from the labours of others.

Before we proceed to examine farther into the general question of the importance of endeavouring to establish in Britain a system of technical education for this department, let us consider the definition and principal heads of the subject before us; and, whilst so engaged, let us take an instance from each division, illustrative of the gain to be derived from an extended acquaintance with the modes of treating it.

The art of mining comprehends all the processes whereby the useful minerals are obtained from their natural localities beneath the surface of the earth, and the subsequent operations by which many of them must be prepared for the purposes of the metallurgist.

In the first place, among these processes must be mentioned, the search for localities in which we may reasonably hope to meet with the minerals occurring either in beds or lodes. It is obvious that a combination of geological and mineralogical knowledge is requisite for success, and that a mere empirical tact obtained in a given district may lead to fatal mistakes in another. Amid the phenomena of the lodes, their frequent heaves and dislocations, and their different appearance when bounded by different rocks, call for close attention; and although from lack of sufficient and well recorded observation, the prin-

ciples upon which a criterion should be founded are far from fixed, we often find that a superior degree of general experience has been rewarded by success, when mere unintelligent working had been completely foiled.

Among the methods of proving the existence of useful deposits, none has yielded greater results, or is more capable of extended application, than the art of boring. For ascertaining the position of coal-seams, and for obtaining a supply of water, bore-holes are frequently sunk in many parts of the country. But we have yet, by a comparison of the practice of different countries, and the adoption of a more economical mode of sinking, where need be, to greater depths, to increase their sphere of utility. At Neusalzwerk, near Minden, a bore-hole has lately been pierced through the trias formations, to the depth of 2,300 feet, for brine springs; and another, at Mondorf, in Luxembourg, to near 2,400 feet, which, though unsuccessful in discovering salt, has supplied a spring of above 21 cubic feet per minute. At these and various bore-holes of less depth in Germany and France, a variety of apparatus has been employed, a complete study in itself, much of which has been serviceable in greatly reducing the time and cost of such operations. We may instance the ingenious instruments of M. Degousée, the "free-falling" cutter of Herr Kind, and the hollow iron rods of Von Œynhausen, as a few of those which are well worthy of attention for the good service rendered in the execution of great works. Again, we know far too little of the routine of the Chinese well-borers, who have succeeded, according to the detailed statements of Father Imbert, in attaining the extraordinary depth of 3,000 feet, by their simple and inexpensive apparatus of rope-boring, an example which has been successfully imitated in the chalk districts of France.

The next division of importance embraces the tools used in mining. One of the greatest advantages which we enjoy over our forefathers is the use of gunpowder in rending a path through the harder rocks, which they with enduring and patient labour were obliged to cut away with hammer and wedge. But the implements employed in various districts differ not only in form and weight, but in their material and useful effect. Let me

only allude to one point: in scarcely any of our mines, whether in the north or south, has it been attempted to use borers of steel; iron is almost universally, with us as in most parts of the continent, the material of which the shank of the borer is composed. Yet in Saxony, for many years past, as also in Derbyshire, and at Ecton, the work has been advantageously carried on with borers of steel alone. Accurate experiments made and recorded at Eschweiler, and at Mannsfeld in Prussian Saxony, have been attended with favourable results; and Mr. Rogers of the Abercarn Collieries has succeeded in proving, whilst sinking a large shaft in hard rock, the value of steel tools, a set of samples of which were placed in the Great Exhibition, and afterwards presented to this Museum. Although the suitable tempering of cast steel is attended with some difficulty to the inexperienced, the following reasons for its preference to the ordinary material have been established, viz., the great saving in wear and tear; the reduction of original outlay, since the stock of steel borers may be smaller than that of iron in a lower ratio than that borne by the price of iron to steel; the diminution of smith's costs for sharpening, and of time lost by boring with a blunted edge, and the greater convenience of carriage in and out of the mine. Farther, the superior compactness of the material transmits the force of a blow more efficaciously to the required point, a fact corroborated by the observation that an iron borer will cut less ground with the same number of blows when new than after being for some time in use; And it need hardly to be added, that in the questions of time, material, and cost, connected with the breaking of ground, we touch on some of the most important elements of economy in mining.

I will not detain you with an enumeration of the points to be dwelt upon in the form of the excavations by which we enter into the earth, whether by the driving of levels or the sinking of shafts under different circumstances; nor, from among the modes of securing them by timbering, masonry, or ironwork, shall I do more than bring to your notice one ingenious application of physical science to these purposes. It is well known that the sinking of a shaft through loose sand or watery rock often besets with great and sometimes with insurmountable ob-

stacles the approach to the useful minerals which lie in firm ground below. On the banks of the Loire repeated efforts to reach the coal measures through a thick bed of alluvial sand had failed, overcome by the great influx of water and loose material; when M. Triger bethought him that the simplest mode of vanquishing the difficulty was to dam back the water by employing a constant resisting force which might be maintained at small expense, in place of a moving power of enormous cost. It was, in fact, to pump into the iron cylinder which formed his shaft such an amount of air that the pressure on the bottom from within should be equal to the pressure from without; and the water was thus prevented from rising above a given height. Placing a cover on the cylinder, through which two pipes are inserted, one conveying the compressed air into it, the other dipping into the watery stratum, he found a stream of water and sand poured through the latter whenever it was unable to escape rapidly enough elsewhere. Then, in order that the men might enter upon or leave their working place without disturbing the equilibrium of the forces, he applied the principle of the canal lock, fitting an upper chamber in his shaft, where, when the upper door was closed and the lower one opened, all was filled with the compressed air; when the lower one was closed and the upper opened, the air-lock was relieved from its superabundant air, and men or materials might be introduced. Pages would be filled with the details of the difficulties met and overcome, and of the successful adoption of the principle in the sinking of larger and deeper shafts; suffice it to say, that M. Triger succeeded, surrounded by water, in joining his cylinder to the solid rock at a depth of 82 feet from the surface, having proved that human life could be supported, and work done, for many hours together under a pressure of 3½ atmospheres. His procedure is marked by manifold advantages, and admits of various applications;—witness the removal of rocks in the harbour of Croisic, on dry ground, whatever the state of the tide. Verily, if Canute had possessed a Triger among his courtiers, he might, to better purpose, have defied the rising flood to touch his royal foot!

We shall be unable here to glance even rapidly over the many systems devised for working out the minerals attained by

the foregoing operations: let us only scan an isolated case. The magnificent seam called the "thick coal" of Dudley has been worked throughout the entire field on a principle which by taking the whole height, 30 feet, at one time, has been attended with such danger as to cause almost weekly some frightful and fatal accidents, and to exercise morally a pernicious influence on the character of the colliers; whilst it has necessitated the leaving of so large a proportion in "pillars" and "ribs," that only from 11,000 to 15,000 tons of coal have been obtained out of 40,000 contained in the acre. Here then is a loss to the national wealth of useful life, and of about two thirds of the finest fossil fuel in Britain, the money value of which would amount to many millions. Yet for twenty years past, in that very district, one group of pits has been worked on a system by which the coal is taken in two successive stages, where the men work in comparative safety, and where, instead of 11,000 or 15,000, 26,000 tons are realised per acre, although the seam is there of less than its average thickness. Consider only for one moment the beneficial effects of improved means of extracting the coal from our mines: it is supposed that the total quantity annually brought into use amounts to above 30 millions of tons; and if an economy of but threepence per ton were effected, by reducing friction, ineffective labour, or other sources of wasted power, a sum of nearly 400,000*l.* per annum would be saved to the country.

We must omit to speak of the modes of transport along the underground roads, of raising the minerals to the surface, and of pumping the subterraneous water, accomplished by an amazing variety of apparatus and machines. Nor can we dwell upon that important subject of ventilation, to which our attention is so often and forcibly called by the fearful catastrophes occurring in our mines from its absence or mismanagement. I would only call attention to the rude method of dispersing noxious gases figured by Agricola 300 years ago, and in some of our districts still adopted, under the term of "brushing out the sulphur," as the only means of rendering a place safe for the men to work in. But although even at that early day more refined processes had been introduced, as evinced by his description of

the ventilating fans, let us compare all those puny means, and the efficiency of ventilation in the great bulk of our collieries with the skilfully applied and fiercely blazing furnaces of some of the great northern mines, where a current of 150,000, or in one case near 200,000 cubic feet of air in one minute are circulated through the devious passages, and rush to the upcast shaft with the velocity of a hurricane.

Nearly related to this division, as regards the question of humanity, is the true construction and the preservation of mining plans. Take an instance in which the loss of 100 lives may ensue from the ignorance of a physical fact. Those familiar with the mining districts are well aware that the great majority of their maps are laid down without any reference to the phenomenon of magnetic variation. If, then, a colliery be in operation on the dip of old workings filled with water, the tapping of which would be death to all employed in the pit, and the maps had been constructed some years previously with respect to the magnetic meridian alone, the variation may in the mean while have so far changed that the exploring drifts supposed by the manager to be going clear of the known danger may, in reality, lead him straight to destruction. The art of surveying is, however, too important and extensive to be included in the lectures on Mining, and will ultimately, we hope, form the subject of a separate course.

The last group of operations to be included is the dressing of ores, on the efficient conduct of which the success of many a mine may depend. Whilst the Schemnitz miner is able to work actual gold ores broken from great depths, which, besides a little lead, contain no more than one part of gold in 228,000 of stone,* and whilst the Russians wash in their stream-works sands containing only one part in half a million, we learn from description that the Californian and Australian are employing processes more rude than what they might have copied from the miners

* In 1841-2, when I passed some months among the mines of Hungary, much had been done and was still doing by my friends the late Oberstkammergraf von Svaiczer and Mr. Rittinger, the Inspector of Stampworks, for the improvement of the dressing of gold and silver ores; and the works at Antal and Illia, near Schemnitz, were well worthy of admiration for their scale and economy.

of three or four centuries since, and that (inasmuch as the poorer part can only be profitably worked in conjunction with the richer) they are actually losing for ever a large proportion of the riches showered by nature upon those lands.

Such are, in few words, the processes which will form the substance of a course of instruction in the art of mining; and it need scarcely to be observed that a preparatory acquaintance with physics, geology, and practical mechanics is indispensably necessary. For this reason it is proposed that the Lectures on Mining shall be given to the students of the second year, already provided with the preliminary studies, some of which have been commenced; but in order to obviate misconstruction, it is proposed during the present season to deliver a concise course, intended simply as an outline of the subject, leaving the more detailed treatment for the ensuing year.

Amid the entire circle of the sciences we can hardly mention one which the accomplished miner may not at some time call to his aid, from the science of numbers, on which all his other knowledge should be based, up to astronomy, which may assist in the construction of his maps. We cannot, indeed, expect that many will become, like Humboldt, (who was educated, and for some time practised, as a miner,*) master in several sciences; but when we add to these the acquaintance with business routine and commercial questions which the manager of mining property ought to possess, is it not clear as the noon-day that for those who desire to excel in this profession a special education ought to be superadded to the training of our schools and colleges? And is it not equally clear that with so vast a field of investigation before him the intelligent inquirer must ever remain a student, whilst only the shallow pretender can affect to be the arbiter of the difficult problems which daily present themselves?

From the examples above adduced I trust that I shall be justified in asserting, that a communication of knowledge, whether of the principles or of the practices involved in mining, must be

* Alexander Von Humboldt was a student at the mining academy of Freiberg, in Saxony, in 1791, with von Buch, Freiesleben, and other coryphœi of mineralogical and geological science.

attended by great pecuniary gain to the country at large. We shall be met, in the outset, by the argument more suited to the Cape Boer or the Chinese than to the progressive Anglo-Saxon, that because our fathers have done very well without it we may easily dispense with any such innovation; and that the immense mineral production of Britain is the best proof that we need not to follow the example of nations unable, with all their schooling, to rival us in that respect. But let us not overlook the great natural advantages with which we have been favoured, nor forget, that although individual perseverance has done much, very much, among us, we must still depend for advancement in a great degree on the experience of others. In good truth "he that neglects the culture of ground naturally fertile is more shamefully culpable than he whose field would scarcely recompense his husbandry: and it is as rational to live in caves till our own hands have erected a palace, as to reject all knowledge of architecture which our understandings will not supply."*

Taking even the present state of our knowledge as a standard, let us balance the argument on such crucial questions as the following. Do cases occur in which mineral substances are neglected from ignorance of their nature? Is it true or not, that others are wasted and lost to the nation by the character of the present operations? Do not crowds of well-meaning adventurers rue their introduction to the mining schemes of impostors? Are not hundreds of human lives sacrificed to a want of precaution and prudence? Is not the condition of machinery and apparatus in a great part of the country very inferior to certain now existing models? Are there not numerous sources of wealth lying unemployed from the uncertainty consequent on a want of former records or present knowledge? No one, I am confident, acquainted practically with our mineral districts, will hesitate in replying, that in all these points great and salutary changes may be made, and that enlarged opportunities of learning accorded to the mine agents must produce their fruits in due season.

As for the miserable plea of ignorance, that the country cannot

* Johnson. Rambler, No. 154.

fail to prosper, in whatever degree her sons may squander the stores of nature deemed inexhaustible,—it but leads the mind back, through many centuries, to an instance of similar reckless boasting, followed by a warning fate. In the palmy days of Athens, when the silver mines of Laurion were vivifying art, commerce, and luxury, Xenophon asserted, in a formal treatise on the revenues of the state, that "whatever number of men had been employed in those silver mines, no diminution had been practically effected in the quantity of the ores;—that there was no limit to the productiveness of the veins, either in depth or in extension, and that their riches, in fine, were inexhaustible."* Let any one contrast such assurances with the beggared state of the land ever since.

I would be far from strictly comparing the conditions of Attica or its people with our own; but we must bear in mind, that in all our mining districts the minerals are extracting at a fearful rate, and each year in an increasing ratio, and that after a certain lapse of time scarcity and increase of price must necessarily follow. In the meanwhile, we have numerous rivals in other and less favoured lands, doing their utmost to make up for natural disadvantages by fostering education and acquiring a sound knowledge of the principles on which they act. In this race they have often been checked by political troubles and peculiarities in their social relations; but, having so thoroughly secured each onward step as to be comparatively independent of the fleeting skill of individuals, they nevertheless press forward again in the same path; and when the day comes that our preponderance in natural treasures is reduced to something nearer equality,—when deeper and thinner coal seams must be wrought, when poorer ores of the metals must be more highly prized, and when the products of our manufactures can only be brought into commerce at higher prices,—then must the star of England's prosperity decline, unless we keep our vantage ground by the

* Μαρτυρεῖ δὲ κἀκεῖνο, ὅτι, εἰργασμενῶν ἀνθρώπων ἐν τοῖς ἀργυρίοις ἐν τῷ παντὶ χρόνῳ ἀναριθμήτων, νῦν οὐδὲν διαφέρει τα ἀργύρια ἢ ἃ οἱ πρόγονοι ἡμῶν ὄντα ἐμνημόνευον αὐτα. . . . Οὔτε γὰρ βάθους πέρας οὔτε ὑπονόμων οἱ ὀρύττοντες εὑρίσκουσι.—*Xen. de Vect.* c. IV.

superior skill and knowledge to which technical education must greatly contribute.

Thus far we have directed our attention almost exclusively to the material advantages, or, in other words, the pecuniary returns to be expected from the cultivation of these subjects. I have dwelt so long on such topics because the main object of the foundation of this course of instruction has reference to that point of view.

But I should ill appreciate the character of this audience, and do violence to my own feelings, were I not, in conclusion, to protest against that debasing spirit which would decry all branches of knowledge except those which are at once commercially profitable, and which would practically inculcate a belief that the acquisition of money is intended to be the great end and aim of human existence. Shall we, for their own sake, examine the works of the architect, the painter, or the poet, and analyze the rules upon which his art is founded, whilst we yet remain indifferent to any one department of the rich storehouse of nature, opened for man's inspection by the Author of all things?

Believe me, that the phenomena of mineralogy, and the principles which regulate them, are, though different in their kind, no less beautiful than those of animal and vegetable life; and they possess the additional source of interest, that they may guide us to the wider sphere of speculating rationally on the constitution of the orbs which roll with us through endless space.

With reason has a Turkish author* said, "Consecrate, O my son, the aurora of thy reason to the study of the sciences; in the vicissitudes of life they are an infinite resource, they form the mind, they polish the understanding, they instruct man in his duties, they delight and amuse us in prosperity, they become our consolation in adversity." Indeed, to the student in his cabinet, no less than to the traveller through Alpine passes, or over regions explored by the skill of the miner, the study of minerals offers at the same time an attractive

* Nabi Effendi, a counsellor of Sultan Mustapha III.

recreation, and an efficient method of disciplining the faculty of observation. The closer we investigate the principles on which their constitution and their physical properties depend, the more are we startled by new and convincing proofs that it is only the imperfection of our knowledge which as yet prevents us from seeing more than the glimmering outline of that harmony which pervades all the works of nature. The system of law, the νόμος ὁ πάντων βασιλεὺς of Pindar, working as surely in the particle which vanishes from our power of sight, as in the loftiest mountain mass, reveals itself with more distinctness the farther we advance; and although the difficulties of inquiry are heightened, so are its pleasures also increased by the ties of brotherhood, which springing hence unite our pursuits with the other natural sciences.

Nor let it be supposed that the details of mining are unproductive of advantage to any but the professional miner. Deep in the bowels of the earth the labour of generations has wrought out edifices no less worthy of admiration than those which the skill of the architect has reared upon her surface; and if, in the latter case, we esteem it desirable to learn so much of the principles of the art as may enable us to appreciate the design of the craftsman, so in the former shall we find in the magnitude of the operations, in the diversity of the natural appearances brought to light, and in the ingenuity of the processes adopted for the maintenance and extension of the works, a harvest of facts no less interesting than suggestive of farther inquiry.

Whatever may be the imperfection of the teacher of these subjects, there is in themselves so much that is exact, so much that is vast, so much, in fine, that is most worthy of man's highest powers, that we may hope, out of the number who will enter with us on the curriculum, to see some few, at least, who will not stop short at that point whence they may obtain their worldly ends, but will persevere towards that goal of higher knowledge which has been, and always will be, the object of the noblest of mankind.

On the Importance of Special Scientific Knowledge to the Practical Metallurgist. (*Being the Introductory Lecture to the Course of Metallurgy. Session* 1851–1852.)

By JOHN PERCY, M.D., F.R.S.

THE subject which I have been appointed to teach in this Institution is essentially practical in its character and relations. In the introductory discourse, which I am now about to deliver, I shall explain the nature and object of the instruction which I propose to impart, and point out what I conceive to be its advantages.

Metallurgy, as at present understood, is the art of extracting metals from their ores, and adapting them to various purposes of manufacture. This definition, however, is not rigidly exact, nor can I frame one in few words that is so.

The etymology of the word "metallurgy" would seem to imply a more extended meaning, and include all the arts in which metals are wrought into objects of utility or ornament; but this is not the meaning now attached to the word.

The metallurgist receives the ore from the miner freed as perfectly as possible by mechanical processes from foreign matter.

The knowledge of the principles of metallurgy is the science of metallurgy. But as the phenomena observed in metallurgical processes relate to physics and chemistry, and as mechanical appliances of various kinds are employed in these processes, it follows that chemistry, physics, and mechanics must be the foundation of the science of metallurgy. In order, therefore, that the student may with advantage enter upon the study of metallurgy, it is essential that he should possess a considerable amount of preliminary knowledge.

The history of metallurgy dates from remote antiquity; and, as Le Play correctly observes, "most of the fundamental phenomena of metallurgy were discovered and regularly applied to the wants of man before the physical sciences properly so called existed."* Metallurgy may, indeed, be said to have given birth to chemistry.

My colleagues having addressed you at some length on the aid which science may be expected to render to the manufacturing arts, it might appear superfluous that I should occupy your attention with the same subject. I shall, however, do so for two reasons:—first, because I shall be able to adduce from my own observation several striking cases in illustration of the advantage of the application of science to practical metallurgy; and, second, because the practice of metallurgy, so far as relates to magnitude of operation, having been developed to an unparalleled extent in this country in the absence of specific public instruction on the subject, it is necessary to justify the providing of such instruction at the present time.

As the word "science," in relation to a manufacturing art, is often used by persons who seem to have no precise idea of it, I shall first adduce a simple illustration of its meaning. There is an ore of copper, composed of copper, iron, sulphur, and silica. When such an ore is subjected to a series of processes consisting of heating it with the access of air, melting, &c., copper is separated in the metallic state. The sum of these processes is termed the smelting of copper. Now in this operation of smelting various chemical changes take place; the sulphur combines with the oxygen of the air, and is evolved in a gaseous state; the iron also combines with the oxygen of the air to produce oxide of iron, which combines with the silica to form a slag, while the copper is separated in the metallic state. We have thus several facts, which are proved by chemical evidence. These facts may, when properly arranged, be said to constitute the scientific knowledge of copper-smelting; and that knowledge implies necessarily a knowledge of the chemical relations of copper, iron, sulphur,

* Le Play. Description des Procédés Metallurgiques employés dans le Pays de Galles pour la fabrication du Cuivre. Paris, 1848.

oxygen, and silica to each other. There are also many other facts connected with copper-smelting; but those which I have selected are sufficient for the present purpose of illustration. Now, the man who conducts the process of copper-smelting in ignorance of these facts has simply an empirical knowledge, in contra-distinction to a scientific knowledge, of the process.

That a scientific knowledge of the process may be important to the man who directs copper-smelting works would hardly seem to require an argument. It may, however, be objected, that the process is often satisfactorily conducted by men whose knowledge is purely empirical. Now the objection would have some weight if it were admitted either that the process is incapable of further improvement, or that the ores upon which such men are accustomed to operate were not liable to vary in composition. But such an admission would be a purely gratuitous assumption; and the ores do occasionally contain unexpected ingredients, which, in the event of precisely the same process of smelting being pursued, would tend in a very sensible degree to deteriorate the quality of the copper produced. Hence, ignorance of the presence of such ingredients on the part of the smelter may occasion pecuniary loss; and, in ignorance both of the causes which thus may injure the copper and of the scientific knowledge of the process of smelting, he is certainly not in the most favourable condition for devising an appropriate remedy. It is true that by a series of blind trials a suitable modification of the process might be stumbled upon; but it is equally true that with the aid of special scientific knowledge there is much more probability of arriving at a solution of the difficulty with far greater economy of time and money. The case which I have put is not imaginary, but real; nor is it, as I know from my own experience, a solitary one. When I treat of copper smelting I shall enter into detail upon this subject.

In support of the general proposition, that special scientific knowledge is important to those who direct metallurgical processes, I shall now present to your notice several cases, most of which I can myself substantiate.

A party purchased a large quantity of a particular ore, at the cost of many thousand pounds. Another party purchased at the

same time a much larger quantity of the same ore, at the same price. To treat this ore profitably, special scientific knowledge was essential. The former party possessed that knowledge, and gained thousands by his purchase; but the latter had it not, and lost money.*

A manufacturer purchased some metallurgical works, and for certain miscellaneous articles on the premises, including a heap of waste product, gave only a very inconsiderable sum. Out of that heap, which in ignorance had been thrown aside as worthless, he realized sufficient to pay for the works, the price of which amounted to several thousand pounds.

An eminent copper-smelter informed me, that his ancestor, in purchasing some old copper-works, obtained in value more copper from the furnace bottoms than the purchase-money. In this instance, perhaps, negligence might be ascribed to the seller, but in that last mentioned the error was the result of sheer ignorance.

In 1841 a patent was taken out for "certain improvements in the manufacture of iron and steel." The invention mainly consisted in soaking the pigs of iron in cold water previously to their introduction into the puddling furnace.†

Again: a short time ago a patent was obtained for plating certain metals and alloys with a particular metal, and a manufactory was erected at a considerable outlay to carry out the invention. It was alleged that the importance of the application consisted not only in the whiteness of the metal employed, but in the economy of the process. Now the metal in question was at that time at least thirty times dearer than tin, and was produced only in small quantity. But the inventor was sanguine, and assured me that an ore containing forty per cent. of it existed in abundance, whereas the fact is, that only a few

* It would be impossible for me, without breach of confidence, to enter into more specific details in the narration of this and the following instances.

† Patent granted to Wm. Turner Green and James Gregory, of West Bromwich, Staffordshire, for certain improvements in the manufacture of iron and steel, May 14, 1841. A report of this patent has not been published, but the original document may be seen at the Enrolment Office.

ounces of such an ore have ever been discovered, of which specimens are rare even in mineralogical cabinets; and the ores which contain it and occur abundantly in nature do not yield more than two or three per cent. of it. This case, it is true, may be regarded rather as indicative of ignorance of mineralogy, than of metallurgy; still it may be appropriately introduced under the present head, as an argument for the necessity of the diffusion of accurate scientific knowledge amongst metallurgists. The inventor speculated on the probability of a demand creating an adequate supply of the metal at a comparatively small cost; but special scientific knowledge would at least have prevented the precipitate investment of capital on such a speculation.

Facts such as I have just mentioned should be a warning to the numerous class of inventors in this country, whose naturally sanguine temperament is liable to disturb the exercise of their judgment. The published records of patented inventions, indeed, furnish a striking commentary on the proposition before us. The diffusion of the scientific knowledge relating to metallurgy would often prevent the reckless expenditure of money on worthless patents.

Very striking instances in support of the same proposition may be derived from the important branch of metallurgy termed "assaying," or the art of determining the quantity of metal contained in its ores, alloys, or certain other compounds. Without a correct assay, it is obvious there can be no certain knowledge of the value of an ore; and without that knowledge, the purchase of an ore by the smelter is merely a speculation. Now by great practice upon some particular class of ores, the merely practical assayer may arrive at accurate results, and yet be entirely ignorant of the science of his art, or, in other words, of the chemical properties and relations of the elements upon which he operates. But if, as I have already mentioned in the case of the copper-smelter, he should meet with an ore containing foreign and unexpected ingredients, which interfere with the accuracy of the method he had been accustomed to practise, he would not, from his want of scientific knowledge, be able to surmount the difficulty, and would consequently, from his necessarily erroneous result, seriously mislead the smelter respecting the

value of an ore. Or he might equally mislead the seller who relies upon his judgment, either by under-estimating the quantity of the particular constituent which he seeks to determine by his assay; or by overlooking another constituent, it may be of great value. In illustration of errors of this kind, I have selected the following instances.

An ore of cobalt from North America was assayed, and alleged to contain twenty per cent. of oxide of cobalt, which at the time was worth about 30*s.* a pound. The assayer, however, had made an important mistake; for what he had estimated as oxide of cobalt consisted of oxide of cobalt and oxide of manganese, in the proportion of two parts of the former to three of the latter; the oxide of manganese being in this instance not only utterly valueless, but positively injurious.

An experienced copper-assayer, on assaying a particular ore, obtained what he believed to be nickel-speiss: that is, a compound of nickel and arsenic. Now, nickel is a valuable metal, being worth at the present time eight shillings a pound. But the supposed speiss contained not a trace of nickel, and was proved to be only a compound of iron and arsenic, a comparatively worthless product. On the ground of this assay, I believe a quantity of ore had been dressed for the market.

The following is a curious and remarkable instance of the importance of accurate chemical knowledge to the metallurgist. The Upper Hungarian Mining Company smelted, during several years, a species of copper-ore termed fahlerz, in ignorance of the fact that it contained mercury, which was ultimately discovered by the accidental observation of a workman. Means were then adopted to collect the mercury, of which the present annual produce amounts to 30,000*l.* in value.*

Not along ago I visited, in concert with my friend Mr. Henry, a tin-plate manufactory. In the first part of the process of tinning there is constantly formed a black powder, which from time to time is removed from the surface of the melted tin. On interrogating the manager, who conducted us over the establishment, it appeared that he was ignorant of the nature of that

* My friend Professor Szabó, of Pesth, is my authority for this statement.

powder, which Mr. Henry on subsequent examination found to contain 62 per cent. of tin in a finely divided state. Our guide suspected that it contained silver; but his knowledge was limited to the fact that, whereas it was formerly thrown into the adjoining river, it was afterwards sold for a few pounds a ton, but now realized ten times as much.

Occasionally a large sum of money may depend upon an assayer possessing a profound knowledge of certain departments of analytical chemistry. Thus, not long ago there was a dispute between the Bank of England and the Mint respecting the recoinage of a million of sovereigns. On melting the gold at the Mint several pounds weight of a metal were obtained which had not been previously detected by the assayer. That metal was chiefly iridium, which had been simply mechanically diffused through the gold, and which, in the state in which it was separated, was comparatively valueless. The question then arose whether the Bank or the Mint should be responsible for the loss; and it was some time before a satisfactory conclusion was arrived at. I do not mean to imply that the slightest blame was due to the assayer in this case, because he had no reason under the circumstances to suspect the presence of iridium in sensible quantity. I relate the fact, simply to show that an assayer of the precious metals may be called upon to determine the presence or absence of iridium in gold, and, I may add, of other metals also, which, for their satisfactory detection, require no ordinary skill in one of the most difficult departments of analytical chemistry.*

It would be impossible to insist too strongly upon the importance of assayers generally receiving sound instruction in the specific department of analytical chemistry, which relates to assaying.

Did time permit I could adduce many more instances in support of the proposition, that special scientific knowledge may be important to the metallurgist. I could mention one case in which, I have been credibly informed, thousands of pounds

* The presence of minute particles of the alloy of osmium and iridium in gold is sometimes very annoying to jewellers and watch-case makers.

worth of gold were lost by a blunder; and others, in which the want of scientific knowledge had occasioned heavy loss; but I have preferred placing before you those instances only upon the accuracy of which you may rely, as I have derived them either from personal knowledge or unquestionable authority. But it will not, I think, be denied, that the instances which I have adduced of themselves afford sufficient evidence of the importance, not to say necessity, of special scientific knowledge to those who are intrusted with the direction of metallurgical works. The interests at stake in such works are frequently very great, and we have seen how injuriously those interests may be affected by the want of such knowledge.

It must not be inferred from the foregoing remarks that I undervalue practical knowledge. So far from this, I am convinced that scientific apart from practical knowledge may in metallurgical establishments lead to most erroneous and occasionally ruinous results. Metallurgy is an art, and, like every other art, can only be acquired by experience. In many processes success depends upon the discrimination of appearances so slight that the eye, in order to detect them, requires to be educated by close and constantly repeated observation. No description, however accurate and minute, would enable a man, though a shrewd observer, to recognise at first such appearances, and consequently to conduct processes in which success essentially depends upon their detection. To understand adequately the force of these remarks, a practical acquaintance with certain metallurgical processes is necessary.

The descriptive expressions occasionally used by the practical man may appear to be vague, and he may not be able to define them in language very intelligible to us; yet we may generally be sure that they express correctly the result of his observation, and have a meaning well understood by himself. For instance, on inspecting a blast-furnace in Staffordshire, I perceived that "tap-cinder" (slag from the puddling-furnace, rich in iron,) was introduced into the furnace with a mixture of iron ores, not then a very unusual and now a common practice. I accosted the foreman of the works, and asked him his opinion concerning the effect which he supposed the use of "tap-cinder"

would produce upon the iron. His reply was, that "cinder has no nature in it." Now the term "nature" expressed his experience of the quality of the iron when "cinder" and ore were smelted together; and, as I knew what that quality was, I knew exactly what was meant by the term in question.

The knowledge of the science of a metallurgical process would of itself be a very insufficient qualification for the man who directs the manufactory. Let a chemist, for example, who may perfectly understand the theory of copper-smelting, but who is entirely ignorant of the practice of the art, attempt to take the management of copper-smelting works, and he would find himself embarrassed at the outset; he would not be able to form a correct judgment in a single step of the process. Without experience he could not decide whether the requisite degree of heat was produced in any of the furnaces, or whether any of the various operations of smelting had been properly effected. Again: let the chemist who has received his education exclusively in the laboratory, and who, consequently, has only been accustomed to deal with small quantities, be simply required to dissolve a ton of copper in sulphuric acid, and at first he would not be a little perplexed: he would find how different the manipulation of the laboratory is from that of the manufactory; he would have to consider of what material he should construct the vessels in which to effect the solution,—of what form and size they should be,—and in what manner heat could be best applied; only the chemist who is himself practically acquainted with the manufactory will well understand the force of these remarks. I have frequently conversed with chemists who have supposed that their chemical education alone rendered them at once fully qualified to conduct operations on the large scale; and who have expressed themselves disparagingly of the practical man. Let such men attempt to conduct the manufactory, and, in all probability, it would soon be seen that the price of their obtaining the requisite practical skill would be heavy loss to the proprietors.

We are thus led to the conclusion, that while scientific knowledge alone will not qualify a man to take the management of metallurgical works, so neither is empirical knowledge

the only qualification desirable in such cases; it is clearly the combination of scientific with practical knowledge that will render the managers of such works in the highest degree competent for their responsible positions. And, accordingly, we find that our manufacturers have begun to appreciate the importance of this combination of knowledge in their managers. I could mention several establishments in which the aid of science has been sought with no inconsiderable advantage. I know that men who have received a metallurgical education on the continent are now employed in metallurgical establishments in this country; and I know many instances of English students seeking that instruction in mining and metallurgy abroad which had not been provided for them at home. It is from the combination of scientific with practical knowledge, especially in metallurgical establishments, that we may reasonably expect improvements in metallurgy. The scientific man, without practical knowledge, is likely to project schemes which, however plausible they may appear in theory, could not be profitably carried out in practice. Without experience of the working of processes on the large scale it would be impossible to form even an approximate notion of the cost of production; and the ignorance of financial considerations which the scientific man has not unfrequently displayed has, I doubt not, in many cases caused the practical man to undervalue, or even deny, the advantage of the applications of science to manufacturing art. On the other hand, the practical man has often elicited the contempt of the scientific man, by propounding unphilosophical and sometimes absurd explanations of the processes which he conducts; and it must not be forgotten that the practical man, in spite of his purely practical pretensions, will generally and, according to my experience, always be found ready with an explanation of any phenomena he may observe: indeed, the practical man, paradoxical as it may seem, abounds in theories, often in the highest degree wild and visionary. From these considerations, the importance of the combination of scientific with practical knowledge in those who direct metallurgical establishments will more clearly appear.

Although the arguments which I have already advanced may

be regarded in some measure as a reply to the objection which, in a former part of this discourse, I anticipated might be urged against the utility of providing public instruction in metallurgy in this country, yet, from its *primâ facie* plausibility, it requires a more specific examination. The objection, it will be remembered, is, that as in Great Britain the practice of metallurgy has attained an unparalleled degree of development, and as this development has been effected in the absence of public instruction in metallurgy, such instruction must now be unnecessary.

By development I mean magnitude of production; but magnitude of production is no certain proof of correspondingly great skill. Let us consider first the special natural conditions under which the development in question has occurred. The largest and most important item of the metallurgical produce of Great Britain is iron; and it is precisely that item which, on comparing the amount of the metallurgical produce of Great Britain with that of other countries, makes the balance so great in favour of the former. Now, the ores of iron exist in extraordinary abundance throughout various districts of this country; and, what is very important in the consideration, the fuel necessary to the smelting of iron exists also in equal abundance, and, for the most part, in close proximity to the ores of iron. We have thus two conditions specially favourable to the production of cheap iron, abundant ore and fuel occurring together; and to these may be added the third condition of denseness of population, and, as a consequence, cheap labour. In no other country* do we find an equally favourable combination of circumstances for the production of cheap iron, not even in North America, where rich coal fields extend over a vast area, and the ores of iron exist in great profusion; for, generally, as the two do not occur together, the expense of carriage must necessarily be considerable. Moreover, as the country is as yet but comparatively thinly inhabited, the expense of labour is greater than in Great Britain. In respect, then, to the capability of the production of cheap iron our own country is at present unrivalled.

* Except, perhaps, Belgium.

But the mere smelting of iron, as compared with some other metallurgical operations, is a simple process. After the introduction of the proper admixture of ores, limestone, and fuel into the blast furnace, the only satisfactory indication of the working condition of the furnace is presented by the character of the slag as it flows out at the bottom. The quality of the metal produced from the same furnace, apparently under the same conditions, varies from time to time, even in two successive tappings.* Hence, as in the process of iron smelting there is but comparatively little opportunity for observation and interference on the part of the manager, and as under apparent identity of conditions the product may vary sensibly in quality, the operation itself cannot, in respect to the opportunity for the exercise of skill, compare with many other metallurgical processes.

But it must not be assumed that because this branch of industry has been generally carried on in this country by men who have not a scientific knowledge of the process, it would not with the aid of such knowledge have advanced to a much higher degree of perfection, whether as relates to economy of production or excellence of quality. Nor must it be assumed that because the production of iron (and in speaking of iron at the present time I mean pig-iron) appears to be a simple process, and because the men who conduct that process have frequently no scientific knowledge of it, science has done nothing towards the development of the smelting of iron in this country. Although we may not be able accurately to trace the history of improvement in many instances, yet we may be assured that the improvements which have from time to time been effected in the smelting of iron have not been altogether the result of accident or blind trial. The observation which I have just made respecting the production of pig-iron will also apply to the manufacture of bar or wrought iron, with the exception that in the latter case there is apparently much greater scope for the exercise of skill on the part of the workman and manager.

There are many problems of the highest interest in relation to the manufacture of iron and other metals at the solu-

* Even in the same tapping there may be several distinct varieties of metal.

tion of which we shall, most probably, only arrive by the aid of science. I have already alluded to the production of a slag termed "tap-cinder" in the conversion of pig or cast into bar or wrought iron. Of this slag thousands of tons have, until quite recently, been thrown away every year, notwithstanding it contains a larger quantity of iron than exists in the common argillaceous or most abundant ores of iron; and when it is introduced into the blast furnace with the ores of iron it tends in a special manner to deteriorate the quality of the iron produced. By the aid of analytical chemistry we are, I believe, enabled to determine why the use of this slag injures the quality of the iron; and thus, having a correct knowledge of the cause, we are in a better condition for devising means to counteract the defect than we should be if that cause were unknown to us.

We import annually a large quantity of foreign iron, especially for the manufacture of steel. In 1850 the importation amounted to 34,066 tons, the value of which may at least be estimated at 500,000*l.** Yet, I presume, if a method should be discovered by which British iron could be satisfactorily substituted for that amount of foreign iron, such a discovery would be regarded as advantageous to this country. Many attempts have been made to effect this substitution, but hitherto with only partial, though, I may add, increasing success. Particular varieties of iron are required for the production of particular qualities of steel; and we are still, in great measure, ignorant of the precise chemical differences between these varieties of iron. But without a knowledge of these differences, the determination of which will require the highest analytical skill of the chemist, we can only make blind attempts to solve the problem in question.

In the smelting of copper there are many points of considerable practical importance which are still very obscure, and which will certainly never be elucidated without the aid of science. Notwithstanding that copper smelting has been con-

* I make these numerical statements on the authority of my friend Mr. S. H. Blackwell, the author of the admirable statistical report on the iron trade in this country, contained in the Illustrated Catalogue of the Great Exhibition.

ducted in this country, during a long period, on a scale of unexampled magnitude, there is one point in the last part of the process,—the operation of "poling,"—which is even not yet clearly understood: I allude to the effect of "over-poling." Researches have, it is true, been made on this subject, but still, as it appears to me, without a decisive result. Again, the quality of the copper produced, not only in different smelting establishments, but in the same establishment, at different times, has been found very sensibly to vary in certain respects, especially of late, in spite of the efforts of the smelter to produce a metal of uniform quality. I know, indeed, that in some instances even smelters of great experience have taken special precautions to attain this end, but still not with constant success. Now it is clear, I think, that in such cases chemistry alone will enable us to determine the causes of this variation in quality, and without a knowledge of these causes the smelter can merely grope in the dark after means to obviate the defect. Already, I know that in some instances chemistry has rendered essential service of this kind. The variations in quality to which I have alluded are frequently not in the slightest degree indicated by the appearances of the metal, and only become manifest in the different processes of manufacture to which copper is subjected; as, for example, in rolling, hammering, and stamping, in dipping, and in the peculiar and sometimes very striking defects which it occasions in alloys. At a future period I shall enter at considerable length upon these points. In illustration of the variations in the quality of copper, I may mention the fact of the very different degree of corrosion by sea-water, observed especially during the last few years in the copper sheathing of the vessels of the navy.

The smelting of lead would also appear to present a promising field for the exercise of special scientific knowledge. In this country two methods of smelting are practised, and in both the loss of lead from volatilization is very considerable, amounting to ten per cent. or more. Accordingly, flues of great length, sometimes exceeding a mile, are constructed in order to effect as completely as possible the condensation of the lead smoke or fume. Other contrivances with the same view have been adopted; the smoke

has been caused to pass through water by means of powerful exhausting pumps, or water has been projected in a finely divided state, like rain, into chambers through which the smoke has been made to circulate; and other methods have also been tried with greater or less success, but all attended with no inconsiderable outlay. Now, as my friend, Mr. John Taylor junior, remarked to me, attention should rather be directed to the improvement of the smelting process itself, by effecting, if practicable, the separation of the lead at a temperature sufficiently low to prevent volatilization. But such an improvement, admitting its practicability, is far more likely to be made by the smelter who, with a practical knowledge of the process, combines the special scientific knowledge relating to lead smelting, than by the man who possesses only the former.

In tin-smelting, also, we meet with some interesting and important problems, which would seem to require the aid of chemistry for their solution. For example, in the manufacture of the best tin-plates, the tin required is of the best quality, and has, therefore, the highest price. Tin of inferior quality, and of less value by some pounds per ton, is unfit for that purpose. Chemistry will alone explain why one kind of tin is suitable, and another not; and when the causes of the difference between one quality of tin and another are known, it is not improbable that a method may be devised for converting tin of inferior into tin of superior quality, the difference of price between these qualities allowing a considerable margin, as manufacturers term it, for the expense of a process by which that conversion might be effected.

I might also, with equal propriety, allude to the manufacture of zinc, which, it is to be hoped, is not incapable of further improvement. There is at present a greater difference between the value of the ores of zinc and the zinc itself than in the case of any other metal.

Another very promising field for the exercise of science in relation to metallurgy is presented by the various metals which have not yet received any extensive practical application. Tungsten, for example, is in this category; it exists in nature in considerable abundance, and is frequently found associated with tin ore, from which it is separated as completely as practicable, and

thrown aside as worthless. It is true that attempts have recently been made to employ certain compounds of the metal in dyeing, as had previously been done thirty years ago; but these attempts have not, I believe, as yet been attended with any great success, or a demand for tungsten would have been created in consequence, which is not the case. Failures, however, should only have the effect of stimulating to further efforts in respect to the application of this metal, which, I confidently predict, will not much longer continue a comparatively worthless substance. Very substantial pecuniary emolument will, certainly, be the reward of the man who shall discover the mode of rendering tungsten extensively subservient to the arts. It is only a few years ago, that, in respect to commercial value, nickel occupied much the same position as tungsten at the present time; but now it is worth 8*s.* a pound, or about ten times more than copper. It is the whitening constituent of the alloy known as german silver. The silver-platers who practise the old method of plating by soldering, as well as those who deposit the silver by the agency of voltaic electricity, employ this alloy extensively, the advantage being that when the silver is worn from any part of an article, the alloy beneath sufficiently approximates to silver in whiteness as to deceive the eye respecting the wear. Some years ago, a compound of nickel, termed pottery nickel, was obtained in the manufacture of compounds of cobalt for the use of the potters, which was sold as low as three halfpence a pound, whereas it would now fetch about 3*s.* 6*d.*

Titanium is another metal, which, like tungsten, evidently exists in large quantity in nature, but which has hitherto only been applied to a very trifling extent in the arts, especially as a colouring ingredient in the manufacture of artificial teeth. I confess I am no believer in useless metals, and, therefore, with equal confidence repeat the prediction which I uttered in respect to the application of tungsten. Then, again, I may mention molybdenum, the only practical application of which is in analytical chemistry; and cerium and vanadium, which, if required, there is reason to believe might be obtained in some quantity. We must not disregard a metal on account of its rarity; for some of the rarest metals have of late been applied with great advantage. I may

mention, for instance, the native alloy of osmium and iridium, which only a very short time ago was confined to the laboratory of the scientific chemist. The alloy occurs in small grains, so intensely hard that the hardest file will not make an impression upon them. The tips of the so-called gold pens are made of these grains; but for this purpose only the larger grains can be employed. The demand for these grains in the pen-manufacture is now considerable, and the price ranges between six and eight pounds an ounce. Iridium has also been applied as a black pigment in painting on porcelain. In intensity of blackness it is said to exceed all other black porcelain colours, which by the side of the iridium-black appear more or less grey. It is only within the last few years that uranium has been employed to produce the delicate canary yellow colour in glass with which we are all familiar; but the demand for that metal is at present so considerable that there is a difficulty in supplying it. Another similar instance of successful recent application is afforded by cadmium, which occurs in small proportion in certain ores of zinc. This metal in combination with sulphur constitutes the finest and most durable opaque yellow colour with which the artist is acquainted. The metal itself has also been used in conjunction with mercury and tin for filling teeth; but certain disadvantages arising from its use have caused it to be abandoned for that purpose. I have expressly been somewhat minute in detailing the preceding instances of the successful application of metals not long since regarded as valueless to the arts, in order to excite and stimulate efforts to promote the application of the other metals which I have mentioned as still without useful application; and, moreover, to encourage the hope of success by showing how extensive a field for application is presented in the various arts.

Having now, as I conceive, sufficiently established the importance of special scientific knowledge to the metallurgist, I proceed to describe particularly the kind of instruction which I propose to impart in this institution. That instruction will be conveyed in two ways, by lectures, and by practical demonstrations in the metallurgical laboratory. The student, however, before entering upon the study of metallurgy, will be required to give satisfactory evidence of his possessing a competent knowledge of general chemistry, theoretical and practical.

In the lectures, a minute description will be given of the characters and properties of the various metals, which are properly the subject of metallurgical inquiry, and of such of their compounds as are of special metallurgical importance; for example, their combinations with oxygen, sulphur, phosphorus, silicon, carbon, &c. Their ores will next be treated of, and special attention will be devoted to the consideration of certain matters, the presence of which, even in small quantity, is liable in a marked degree to affect the quality of the metal extracted. The processes of separating the metals from their ores as prepared by the miner will be fully described; and this description will comprise ample details respecting the apparatus and mechanical appliances generally which are required in metallurgical operations, as furnaces, crucibles, blowing-engines, and rolling-mills. The various materials employed in the construction of furnaces, as fire-clay and fire-stones, will be carefully passed in review, together with the kinds of fuel used. The adventitious products which are obtained in any metallurgical processes, as the various kinds of slag or scoria, and a knowledge of which may frequently be of great practical importance, will be discussed at considerable length. The cost of production, and the more important applications of the metals, especially as alloys, and to electro-plating, will receive prominent attention, as will also the theories of the various processes described.

In the laboratory, practical instruction in assaying will be given, and in those special departments of analytical chemistry which have a particular and important bearing upon any given metallurgical process. The various methods of assaying in the case of any given metal will be compared by experiment. The student will also be specially instructed in the use of that invaluable instrument, the blow-pipe, which is not only constantly employed in the discrimination of minerals, but may occasionally be advantageously used in quantitative assaying. To those who may travel in distant parts of the world, the use of the blowpipe cannot be too strongly recommended, as it frequently affords the readiest and most accurate means of determining the nature of ores; added to which, its extreme portability is a very important consideration to the traveller.

Moreover, I shall endeavour to adapt the source of study in the laboratory to the special department of metallurgy in which it is most important that the student should become proficient. Thus, in the case of a student desiring to acquire the special scientific knowledge relating to lead-smelting, I should direct his attention to that part of analytical chemistry which would enable him to ascertain the precise composition of the ores of lead and of the adventitious products obtained in lead-smelting, as lead-slags and lead-fume; and I should also require him to demonstrate by experiment, as far as practicable in the laboratory, the re-actions which take place in the process of smelting.

The lectures will be illustrated by specimens, diagrams, and models; and I may remark that in metallurgical lectures the illustrations presented to the student are of great practical value. It is essential that he should see, and examine carefully for himself, the specimens which illustrate metallurgical processes. No description, however accurate and minute, could in many cases convey to his mind precise notions of the external characters of substances with which it is important for him to be familiar. In the process of poling copper, for example, small portions of metal are taken out of the furnace at short intervals, until it presents certain specific appearances which indicate the condition of the copper, and the period when it is necessary to arrest the operation. In the smelting of iron also, certain appearances of the slag furnish characteristic indications of the working condition of the furnace. But these appearances must be seen to be understood.

The museum, I am happy to state, already possesses a metallurgical collection of considerable value, and which will, I trust, at no distant period become one of the most perfect in Europe. The illustrations of the principal metallurgical processes of this country as the smelting of iron, copper, lead, and tin, and the manufacture of steel, are very satisfactory. The foreign collection is rapidly increasing, and will be found of great practical utility to those who direct metallurgical establishments. Indeed I know that many gentlemen connected with such establishments have visited the museum, and expressed their appreciation of the important practical bearing, especially of the foreign collection.

I may be permitted to add, that in addition to the collection arranged in the museum, I shall be able to illustrate the lectures by an extensive series of specimens which I have myself been engaged in forming during the last twelve years. This collection contains numerous examples of the defects which occur from time to time in the working of certain metals, and which frequently depend upon the presence of foreign bodies in minute proportion which have escaped detection by the smelter.

In regard to models, the metallurgical department of the museum is also in a promising condition. The metallurgist on visiting the model-room will observe that the metallurgical models have not been constructed for the purpose of amusing the casual spectator, but of instructing the student. Each will be found to possess some special feature of interest in relation to practice. The collection comprises models of various furnaces, of a blast-engine, a very beautiful and complete model of the steel works of Messrs. Naylor, Vickers, and Co., munificently presented by them to the Institution, &c.; and to these may be added apparatus used in assaying, including that of Gay-Lussac for assaying silver, (now adopted at most of the continental mints), crucibles, and other metallurgical instruments.

Having explained the nature of the instruction which I propose to impart in this Institution, I may in a few words state what I do not pretend to teach. I do not pretend to teach practical smelting, or that knowledge which can only properly be acquired by experience in the manufactory. But I do hope to be able to communicate information to the student which he will be able to apply with great advantage when, at a future period, he may be engaged in the practice of metallurgy on the great scale, by which he will be prevented from the commission of blunders such as I have mentioned, and be placed in the best possible condition for effecting some of the many desirable improvements in metallurgical processes.

It will doubtless have been remarked, throughout this introductory discourse, that I have considered the subject of instruction in metallurgy exclusively in relation to practice, or in other words, to speak plainly, in a pounds-shillings-and-pence point of view. I have done so for special reasons. This Institution

professes to be a School of Mines, the chief object of which should be to render science subservient to manufacturing art; or, what is equivalent, disguise it by words as we may, to make science remunerative. Our practical metallurgists may be men of large hearts and philanthropic views respecting the application of science to the benefit of man; but if we wish to urge upon them the importance of combining scientific with practical knowledge, we must demonstrate that that combination will be of pecuniary advantage to themselves. What care they, if deficient of a taste for science, about any novel and ingenious application, if it cannot be made a source of profit? What inducement can they have for investing capital to carry into practice an invention, however beautiful and attractive in a scientific point of view, apart from the consideration of gain? If we address men of business on the applications of science, we must take the business view of the matter; and, as from the very nature of my subject, I must be supposed to be speaking to men who either are or may become interested in metallurgical establishments, I have felt it incumbent upon me to speak as I have done.

But let it not be imagined that the study of metallurgy has no attractions for the man of science: so far from that being true, it is a study abounding in problems of great scientific interest, and affording ample scope for the exercise of the highest powers of research; and while the lover of abstract science will discover in it much to reward his attention, to the man who delights in the application of science to the useful purposes of life it presents peculiar charms. To the antiquarian also it will often be found to render good service; for, as the working of metals dates from the earliest period of man's history, the remains of ancient furnaces and the products of ancient metallurgical skill not unfrequently become the subjects of archæological inquiry. It is interesting, moreover, to trace the history of the metallurgic art, and to note how the rude and laborious processes of former times have gradually acquired the marvellous development which we observe in Europe at the present day. In order to form a vivid conception of this progress, we have only to witness the Hindoos toiling laboriously

at their bellows made of skin, to extract a few pounds of iron from their little furnace, scarcely larger than a chimney-pot, and then to direct our attention to the gigantic blast-furnace of modern times, urged by a blast-engine, requiring for its movement the equivalent in steam-power of a hundred horses, and yielding upwards of two hundred tons of iron a week.

As the character of this discourse is essentially practical, I should wish, before concluding, to guard myself from the imputation of undervaluing knowledge, whether literary or scientific, which appears to have no direct practical bearing. It would be furthest from my intention to utter a word in disparagement either of polite literature or abstract science. In this utilitarian age there is a danger of forgetting that the human mind is destined for a higher purpose than that of being wholly absorbed in the material realities of life. There is no incompatibility between the pursuits which elevate, refine, and delight our taste, and those which we are called upon to follow, as well for our personal advantage as for the benefit of our race. In contemplating the marvellous triumphs of human ingenuity at the present epoch of unexampled progress, we should be careful not to depreciate unjustly the character of the education which we received in youth; and we should bear in mind that, although that education may not have made us acquainted with natural objects and phenomena to the extent we might desire, it has yet been the means of subjecting the various faculties of our minds to a most salutary and invigorating discipline.

In conclusion, permit me to impress upon your attention that the chief object of the present discourse is to show the importance of special scientific knowledge to the metallurgist; and the proof, it will be borne in mind, rests chiefly upon the instances adduced in which the want of that knowledge has been shown to have occasioned pecuniary loss. But if the proof be admitted to be satisfactory, it will then follow that the diffusion of such knowledge by public instruction must be of public advantage; for in proportion to the success with which the metallurgic art is practised in this country will the interests of the whole population directly or indirectly in no inconsiderable degree be promoted.

GOVERNMENT SCHOOL OF MINES, AND OF SCIENCE APPLIED TO THE ARTS.

MUSEUM OF PRACTICAL GEOLOGY.

The importance of the Mineral Wealth of the United Kingdom far exceeds that of any other European State, and furnishes four-ninths of the raw mineral produce derived from all Europe. Although the annual value of the mineral produce of this kingdom amounts to £24,000,000, and the capital and labour employed in its extraction and application represent a much larger sum, no school, having for its especial object the instruction of persons engaged in mining operations, has yet been established in the United Kingdom.

Mining Schools have long existed in France, Russia, Prussia, Saxony, Austria, Spain, Sweden, Denmark, and other countries even less connected with mining, and their practical value is recognized by the fact, that the respective Governments of these States have found it necessary to develope still further the educational resources of such institutions. The want of similar establishments in this country has long been felt in mining districts, and has been expressed both in Parliament and in memorials addressed to the Government. In the Report of the Committee of the House of Lords, (1849), the Committee observe, that, "among those best qualified to speak "upon this point, a want appears to be felt of facilities for acquiring mining "education such as are provided by the mining schools and colleges established in the principal mining districts of the continent, apparently with "the most beneficial effects." Memorials have been presented from the principal mining districts of the kingdom, urging this want, and indicating the Museum of Practical Geology as the proper institution to be converted into a mining school. In consequence of these representations, and of the enlargement of the Museum, the Government have determined to apply the resources of the Institution to public instruction in Mining, and in the applications of science to the arts.

The Collections of the Museum are now made available for educational purposes. The laboratories and working rooms of the several departments are so arranged and organized, that systematic studies in Chemistry, Metallurgy, Geology, Palæontology, Physics, Mineralogy, and Mining, are given under the direction of the officers of the respective departments. The Museum itself is of an essentially practical character, and was primarily

intended to bring science to bear on geology in its application to the useful purposes of life; its officers were selected with a view to carry out the educational character of the institution, recognized shortly after its formation by an official letter of the Chief Commissioner of Her Majesty's Woods, and sanctioned by the Lords of the Treasury.

The following is a list of the Officers entrusted with the courses of instruction:—

PRESIDENT.—Sir HENRY T. DE LA BECHE, C.B., F.R.S.

CHEMISTRY, applied to the Arts and Agriculture	*Lyon Playfair*, Ph. D., F.R.S.
NATURAL HISTORY, applied to Geology and the Arts	*Edward Forbes*, F.R.S.
MECHANICAL SCIENCE, with its application to Mining	*Robert Hunt*, Keeper of Mining Records.
METALLURGY, with its special applications	*John Percy*, M.D., F.R.S.
GEOLOGY, and its practical applications	*A. C. Ramsay*, F.R.S.
MINING and MINERALOGY	*Warington W. Smyth*, M.A., F.G.S.

The educational course of this School differs essentially from that given in colleges where general education is the primary object. Although it is intended to give general instruction in science to those who may require elementary knowledge, still, the chief object of the institution (to which everything else is made subsidiary) is to give a practical direction to the course of study, so as to enable the student to enter with advantage upon the actual practice of mining, or of the arts which he may be called upon to conduct. It may therefore be desirable to call attention to the peculiar features of the institution, and to the courses of lectures given by the respective professors.

THE MUSEUM.

The Geological Survey of the United Kingdom being carried on in connexion with the Museum has afforded great facilities for making complete collections illustrative of the applications of geology to the useful purposes of life. These collections contain an extensive series of rocks stratigraphically arranged, with reference to their mode of accumulation, and the subsequent action of various causes upon them; of fossils classed in the order of geological time; of specimens illustrative of the ores of the useful metals, of their mode of occurrence, and of the methods of preparing them for smelting; of mineral substances used for constructing public works and buildings, and of those employed for ornamental purposes, or for the useful arts in connexion with chemical or metallurgical manufactures. The processes of converting these raw materials into industrial products are carefully exhibited, and illustrations of the finished products are also displayed. The various arts connected with the mineral resources of the country are illustrated by specimens showing varieties or peculiar excellencies of manufacture.

Models of Mines, Mining Tools, and Working Models of Mining Machinery are collected, with the view of exhibiting the various modes of

working carried on in different districts. The Museum is open to the public for the first three days of the week, the remaining days being reserved for study.

GEOLOGICAL SURVEYS.

The Geological Surveys of the United Kingdom are carried on under the general direction of SIR H. T. DE LA BECHE, and their central office is at the Museum. In this office the maps and sections are prepared and deposited. The field surveys are carried on in the localities under examination for the time being, and instruction in the field in the various departments of Geological Surveying is given by the Mining, the Geological, and the Palæontological Professors.

OFFICE OF MINING RECORDS.

This office, superintended by MR. Robert HUNT, is established for the preservation of Mining Records. The absence of these needful documents was found to be the cause of much waste, either in attempts to work in localities where there is little prospect of success, or where from a want of proper knowledge of the old workings much useless expenditure is incurred. Numerous copies of plans and sections of mines, and many important statistical mining details, are deposited in this office, and are made available for the instruction of students.

LABORATORIES.

Two laboratories, one for general, practical, and analytical Chemistry, under DR. LYON PLAYFAIR, the other for Metallurgy and Assaying, under DR. PERCY, are established in the Museum. Students are, under certain regulations, admitted into the Laboratories for the purpose of receiving instruction in the analysis of minerals and ores, and of the methods used in applying them to useful purposes in the arts.

Unless the student has already become acquainted with Practical Chemistry, it is requisite to pass through the Chemical laboratory before entering that for Metallurgy, as the latter requires previous chemical knowledge before its study can be usefully entered upon.

PALÆONTOLOGICAL DEPARTMENT.

As the relative age and sequence of geological formations are, to a great extent, determined by the fossils they contain, it has been found necessary, in the prosecution of the Geological Survey, to attach a department of Natural History, under the direction of PROFESSOR E. FORBES, where the organic remains contained in the sedimentary rocks of the British Islands may be examined and preserved. Extensive collections of these fossils are now made and arranged, and are used for the instruction of students.

Regulations as to Admission.

Persons desirous of entering as matriculated students, with a view of eventually obtaining the diploma of the Institution, must be at least 16 years of age, and will be required to bring certificates or other evidence of their having received a sufficient preliminary education. They shall pay *thirty pounds* in one sum on entrance, or two annual payments of *twenty pounds* each, for admission to all the courses of lectures extending over two years, and field instructions, according to the regulations of the Institution, and shall have the privilege of studying in the Museum and Library.

The charge for instruction in the laboratories (which is not included in the above) is *thirty pounds* for the session of ten months, or *fifteen pounds* for the term of five months. The laboratories are open to occasional as well as matriculated students.

Occasional students are admitted to the lectures on payment of *four pounds* for each course of above 30 lectures, and *three pounds* for the course of 30 and under.

Officers of the Army and Navy, either in the Queen's or the Honourable East India Company's Service, as also managers and agents of mines (upon certificate from a magistrate of the county in which the mines are situated, that they are so occupied), are admitted to the lectures at half these charges.

Field instruction in Geology, Mineralogy, and Palæontology will be given to a limited number of occasional students, at a charge of *five pounds* per month.

Exhibitions.

His Royal Highness Prince Albert has intimated that His Royal Highness the Prince of Wales has grantedto the School of Mines two annual exhibitions of thirty pounds each, to be held for two years, and to be called "The Duke of Cornwall's Exhibitions." These will be competed for by examinations of the matriculated students, at the termination of their first year's course.

Particulars respecting the times of Lectures, and all other information, may be obtained by application to Mr. Trenham Reeks, at the Museum of Practical Geology, 28, Jermyn Street.